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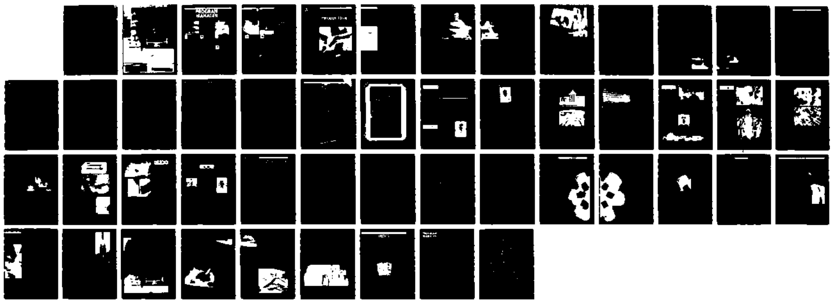

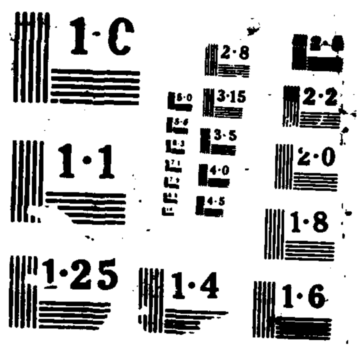
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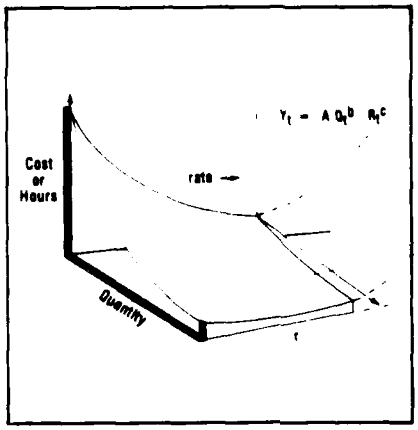

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Cover: One of the most important changes in the amphibious tactics of the Marine Corps on the expanded battlefield of the 1990s will stem from improvements provided by new ship-to-shore systems, such as this tilt-rotor MV-22A Osprey.

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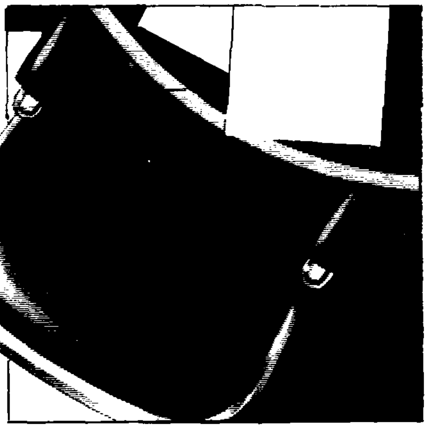

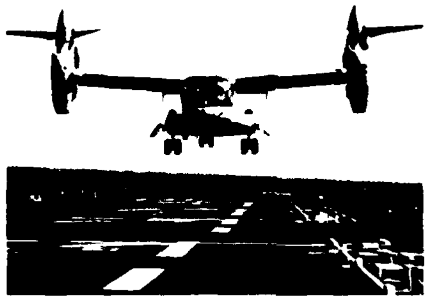

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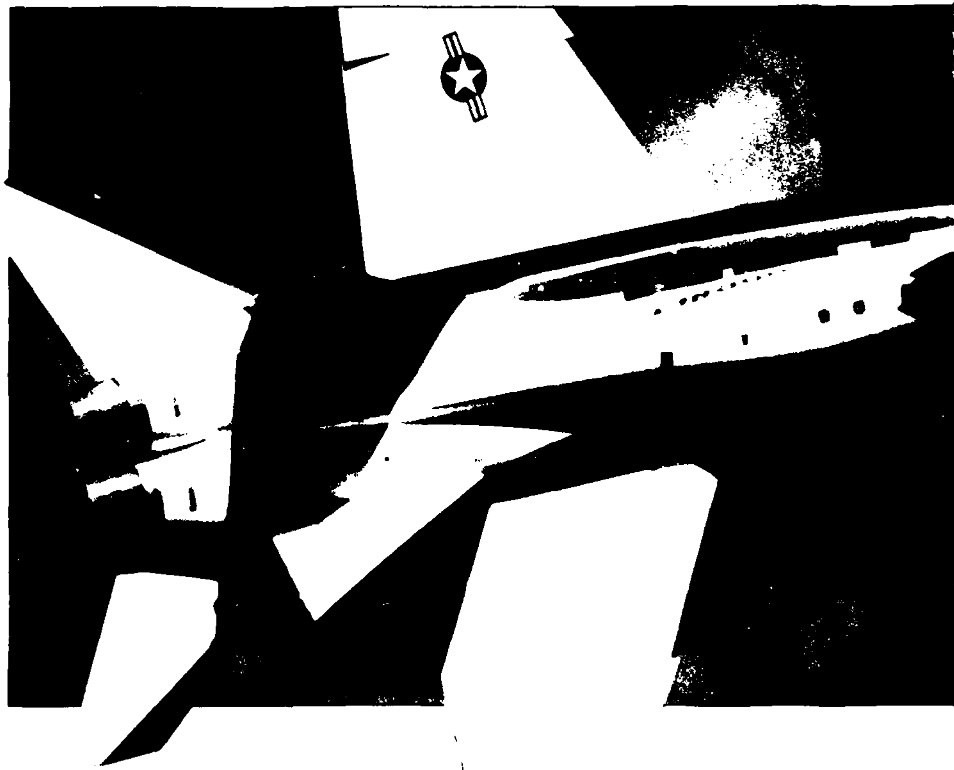
DATA TRANSFER

CODEVELOPMENT AS A PRECURSOR TO PRODUCTION COMPETITION

Background and Issues

Dr. Michael N. Beltramo



A major impediment to establishing effective competition during the production of weapon systems has been the transfer of technical data from the initial source (i.e., developer) to a second source. This problem is manifest in several ways, some of which are noted below:

—Claims by the developer that all or some of the design or manufacturing data are proprietary.

—The available technical data are inadequate or incomplete and thereby do not enable production by a second source without sufficient effort to augment the data.

—The time required to transfer the technology in order to qualify a second source to produce the required item would exceed the period during which meaningful competition could be held because a large portion of the required quantity would have been built.

Several years ago, a procedure was identified which would seemingly resolve most of the problems at the prime contractor level associated with technology transfer leading to competitive production. It was called fusion-fission whereby contractors would team during development and compete during production. This process is now being referred to as collaboration or joint venture teams and is being implemented for several new programs. (A major battle is being fought by subcontractors and vendors over government usurpation of their proprietary data rights. It is not apparent what effect, if any, this acquisition strategy would have at that level.)

This paper examines establishment of codevelopment programs where production competition was not an issue in order to examine motivations and associated costs related to teaming. Then, current Department of Defense systems acquisition programs where the development teams are being formed as a precursor to production competition are considered with respect to their important technical, cost/quantity and organizational characteristics. Finally, issues are identified which should be considered before adopting joint venture development teams as a precursor to production competition.

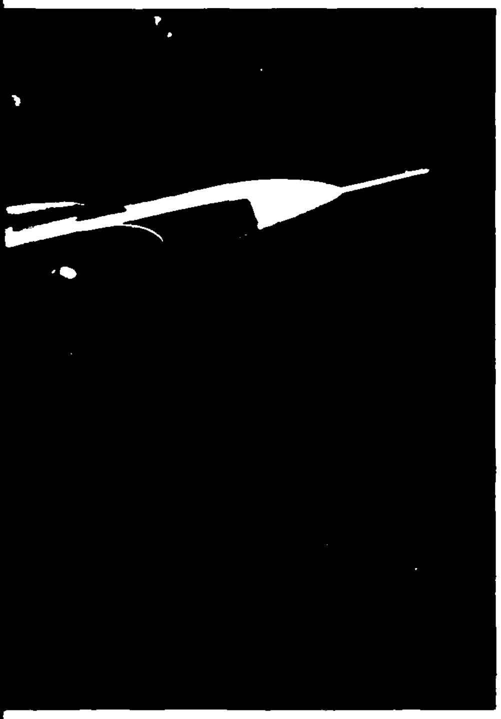
Review of this material does not imply Department of Defense endorsement of factual accuracy or opinion.

It is important to note at the outset that a primary motivating factor for all codevelopment efforts has been anticipated cost savings. But, in most cases the savings have been based upon sharing expenses among two or more prospective users of an identical or similar item. And the projected savings are relative to what it would have cost each user to develop the item separately; in most cases the total development cost has been considerably greater than for a single developer. Also, when single assembly lines have been established, economies of scale have yielded further savings in comparison with two or more firms producing relatively small quantities.

Different Kinds of Codevelopment Programs

Recent coproduction programs have had a strong international flavor whether they were exclusively foreign

F/A 18 Hornet



ventures or had both U.S. and foreign participation. Therefore, it is appropriate to consider four categories of codevelopment programs in order to identify important similiarities and differences. The categories include: foreign/foreign, foreign/U.S., U.S./-U.S. with cooperative production, and U.S./U.S. leading to competitive production.

Although there are notable exceptions (e.g., French Mirage series and Swedish Viggen and Gripen), many current and planned Western European combat aircraft programs have been codevelopments. The reason is clear: The high development cost and limited quantity requirement of any single nation would lead to an uneconomic if not unaffordable unit price without the involvement of partners to share development expenses and provide economies of scale during production. However, economic benefits do not result without a price; as organizational complexities, and political and military compromises increase as the number of partners increases.

The United States recently has been involved in several international laboratories. Perhaps the most representative in many respects is the U.S./Great Britain (McDonnell Douglas, Pratt & Whitney/British Aerospace, Rolls Royce) AV-8B aircraft. The U.S. participation in the AV-8B program was motivated by a desire to exploit British inventiveness in the field of thrust-vectored technology, while British cooperation was based upon a desire to increase sales. It may be viewed as successful in terms of accomplishing those objectives. Yet, RDT&E costs in excess of $1 billion seem high given the program's inherited assets and modest goals.

Other U.S./foreign codevelopment programs have had mixed results. The Multiple Launch Rocket System involving the United States, Great Britain, France, Germany and Italy has developed an organization to coordinate effectively the actions of the many firms involved. The Roland missile program proved unable to resolve technical and operational differences among the participants and was ultimately cancelled.

There have been many codevelopment programs in the United States in the sense that two or more associate contractors have collaborated to design and develop a single end-item. However, in most cases, the firms have each contributed a discrete element of expertise and have not had overlapping responsibilities. The F-18 program is a notable exception. The F-18 was originally a Northrop concept that evolved from the firm's P-530 Cobra/YF-17 lightweight fighter design of the late 1960s and the early 1970s. After losing to the General Dynamics F-16 for a large Air Force and four-nation European NATO lightweight fighter requirement, the YF-17 was selected by the Navy in 1975 for its own lightweight fighter mission, and redesignated the F/A-18. Northrop teamed with McDonnell Douglas for the Navy fighter competition because of the McDonnell Douglas experience in the development and production of Navy carrier-suitable aircraft.

The F-18 program initially experienced cost, schedule and performance problems. Although it would be inappropriate to fix the blame for program problems to joint contractor involvement, it could be argued that this organization complicated coordination and made it more difficult to establish responsibility. (These problems were overcome largely as a result of threatened competition from A-6 and F-14 aircraft.) The RDT&E costs for the F-18 seem high given the fact that it incorporated approximately 80 percent of the YF-17's design.

A key point that cannot be overstated is that it is difficult to reasonably assess the appropriate magnitude of development costs for programs with a single contractor. Thus, it is impossible to estimate an increase caused by a codeveloper after the fact.

Codevelopment Programs Leading To Production Competition

Joint development programs as a precursor to annual production competitions may be an idea whose time has come ... or it may simply be a "nice try." It is too soon to tell. However, at least six such programs are underway in various stages ranging from concept development to prototype production. Their progress, organization and procurement strategies are reviewed briefly below.

ASPJ

The airborne self-protection jammer (ASPJ) is designed for use on Navy (F-14, F-18 and AV-8B) and Air Force (F-16) aircraft. Three teams of electronic warfare contractors were formed in 1977 to compete for the Phase 1 development contracts, which resulted into awards for Phase 2 of the program which was won by ITT

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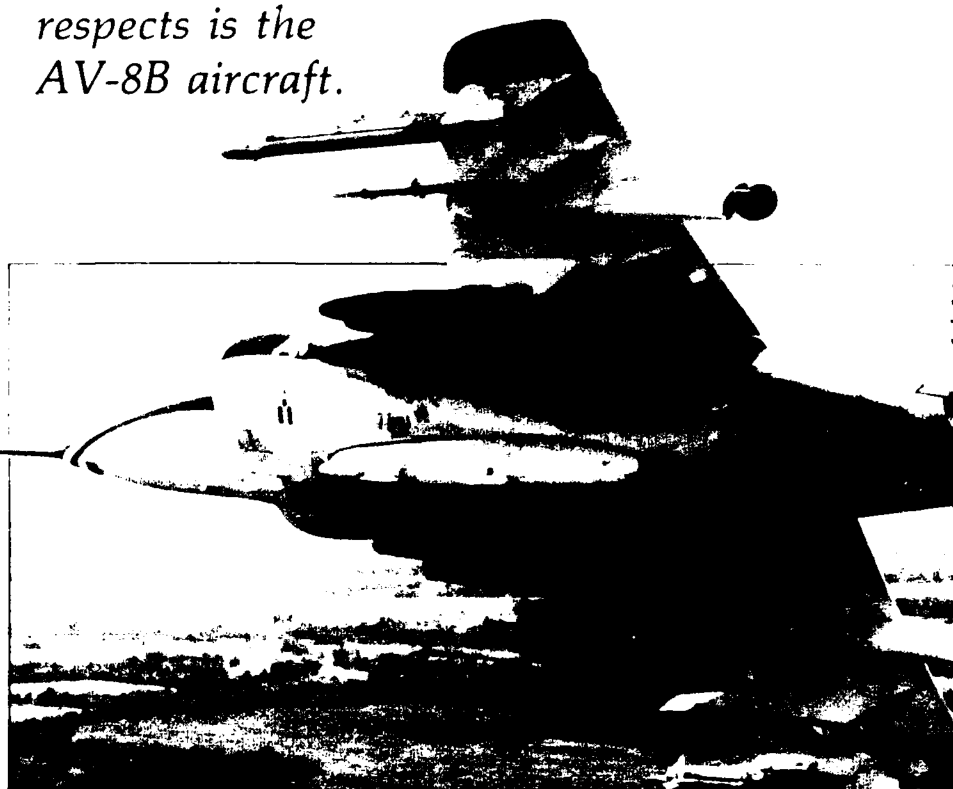
Avionics/Westinghouse. The ITT and Westinghouse will compete for production awards.

Under the Phase 2 enginering program, a total of 16 engineering development model/prototype production models are on order. The contract requires each of the companies to construct at least two EDM systems and eight comprehensive power management systems. After initial production of about 100 systems, the two companies will become competitors to bid for shares of each year's procurement. The procurement plan caused the development work to be divided so that each firm would be equally capable of producing the system. Therefore, each firm received about half of the full-scale development program cost.

The ITT was assigned responsibility for the overall design of the high- and low-band transmitters, the signal processor and the combined augmentation transmitter-receiver. Westinghouse was responsible for the high- and low-band receivers and the pod-mounted version of the system. Further, each company shared responsibilities for designing and producing some of the plug-in modules within a line replaceable unit for which the other had overall responsibility. For example, ITT was responsible for designing and producing two of the 12 plug-in modules used in the two Westinghouse-responsible receivers. Westinghouse designed and built two out of eight circuit cards that go into the signal processor for which ITT is responsible. Program management is at ITT Avionics but the deputy program manager is from Westinghouse.

Delays in the ASPJ program and questions related to its cost effectiveness have caused Navy officials to reevaluate their continued participation. Specifically, the Navy has questioned whether ASPJ is a cost-effective answer to the threat, especially because of uncertainties about its reliability and whether it will be used properly in the heat of combat. Some Navy officials believe that expendables such as chaff are the most cost-effective way to proceed at this time. This is ironic given the fact that many of the development problems have been attributed to the requirement to constrain severely the ASPJ volume to enable it to replace the ALQ-126B on the Navy F-18. In any case, the Air Force is still supporting the ASPJ and has opposed the Navy's requested intervention by the Department of Defense as an arbitrator by arguing that operational testing at this point will only delay the program further.

The United States recently has been involved in several international laboratories. Perhaps the most representative in many respects is the AV-8B aircraft.



Current problems notwithstanding, the quantity and cost of the ASPJ program are such that two developers and producers were feasible as more than 3,000 units may be required at a total cost of more than $6 billion. Also, the initial ASPJ program manager indicated that electronic warfare technology has a very short half life and, therefore, firms were willing to cooperate during development because their current proprietary designs would not be of significant value for future programs.

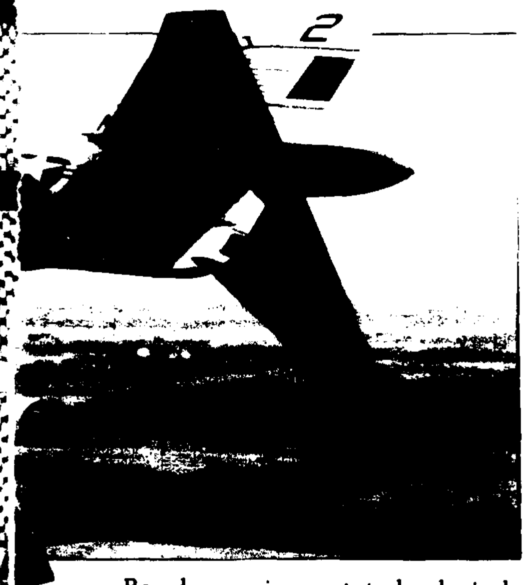
INEWS

The Integrated Electronic Warfare System (INEWS) is planned for use on the Air Force Advanced Tactical Fighter and the Navy Advanced Tactical Aircraft. The INEWS will integrate the functions currently performed by separate systems into a single system. These functions include: radar/threat warning, jamming and power management receiver-processor used in some jammers, missile detection/warning, laser-radiation detection/warning and jammers for use against infrared (heat-seeking) missiles. The target unit cost of the system is between $1.8 and $2.8 million.

Five teams were funded in July 1984 to perform concept definition studies under Phase 1A. Two teams (TRW/-Westinghouse and Saunders/General-Electric) were recently selected for Phase 1B, which involves design refinement and risk reduction studies. One team will be selected around mid-1989 for Phase 2, a 60-month full scale development program.

Phase 3 production is scheduled to begin in mid-1993, with the winning team splitting to compete for relative shares of production quantities. This procedure is similar to one pioneered by the Navy for the ASPJ.

The INEWS represents the first attempt to integrate Very High Speed Integrated Circuits (VHSIC) into a major weapon system and is therefore a significant advancement in the state-of-the-art. Thus, the program should benefit by a teamed development approach which combines diverse problem solving abilities. But the program may be accelerated to keep pace with the new ATF schedule (see below) which could cause problems due to the typically slower reaction time of development teams compared to a single development contractor.



Based upon size, cost, technological complexity and long-term significance of the INEWS program, joint development teams make sense as an abstract concept. It remains to be seen whether it can be applied effectively and whether organizational problems that are seemingly inherent with such endeavors can be overcome.

V-22 Osprey

Another program underway that is utilizing the joint venture development team concept to be followed by competitive production is the U.S. Navy/Bell/Boeing Vertol V-22 Osprey joint services vertical lift aircraft. The program structure is similar to that of the ASPJ with some basic changes to adapt it to the specific characteristics of the V-22. Design and development work on the V-22 is shared equally between the two partners, with Bell responsible for the wing and tilt-engine propulsion packages and Boeing responsible for the fuselage. The division point between the two work shares is the wing swivel, around which the wing rotates to a stowed position parallel to the fuselage, reducing the size of the aircraft for stowage on aircraft carrier main and hangar decks.

Bell and Boeing have exchanged teams of engineers who perform a technical liaison function in the other partner's facility. Both also have CADAM so that they can access each other's drawings.

Ten airframes will be built during the full-scale development phase. Six will be flight-test aircraft and four will be non-flying vehicles for static, drop, fatigue test, and ground test. Bell and Boeing each will build their portions of the first 10 aircraft and exchange sufficient elements to permit each to build five airframes. Each company will operate three of the flight-test aircraft.

Operational V-22 aircraft will be purchased in a series of production lots starting with a Lot 1 pilot production batch of 18 aircraft in 1989. Although questions concerning when the two partners shift to competitive bidding on the production have not been fully resolved, the partners are proceeding as ıt the first lot of 18 units will be competed.

Unanticipated and/or unresolved problems that have arisen for this program fall within the following areas:

—Proprietary data has not been an insurmountable problem between the partners although each has had to relax restraints on the exchange of technical data that they otherwise would have been reluctant to share. However, the ownership of data rights has become an issue with many subcontractors.

—The establishment of dual production lines is an expensive proposition at best; however, this becomes an even greater issue when they are instituted during pilot production as inevitable changes become more costly.

—Special tooling and test equipment funding for the program may cost nearly $1 billion. The Navy's new policy that requires contractors to fund tooling and recover costs over the life of the program raised issue regarding indemnification if the program is cancelled before they are fully reimbursed. The program was delayed pending resolution of this issue. But it was eventually agreed that each contractor would spend $300 million and the Navy would be liable for an equal amount.

—Cost-Effectiveness Considerations. After the tooling agreement was reached, the full-scale development milestone continued to be delayed because of Department of Defense contentions that the Navy had not fully considered alternatives to tilt rotor systems in this cost and operational effectiveness analysis. This was resolved when the Navy agreed to an additional cost review at the end of the first year following several critical design reviews. The R&D costs for the V-22 are estimated at $1.8 billion and total program costs are estimated at $38.6 billion.

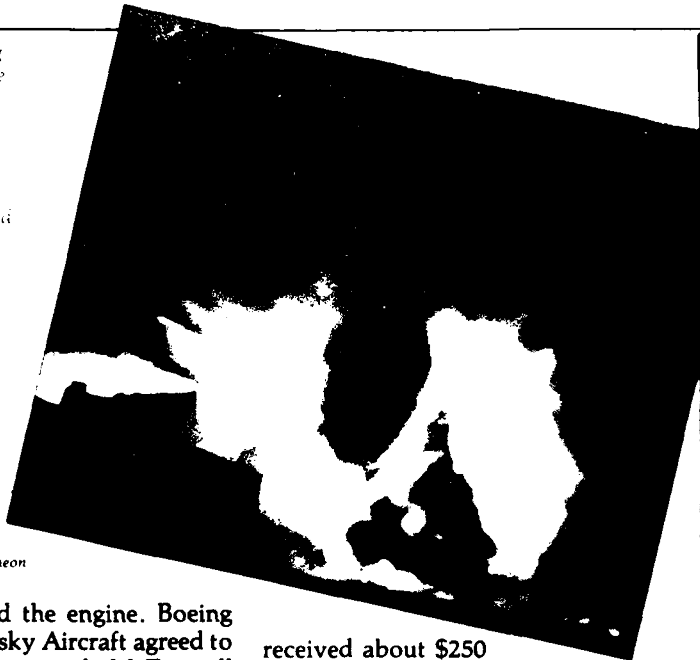
—Production quantity is a serious problem that is not being discussed openly. The total planned buy of 913 aircraft is divided as follows: 552 for the Marine Corps, 231 for th Army, 80 for the Air Force and 50 for the Navy. This implies (assuming an 85 percent learning curve slope and a 50/50 split) that recurring production costs would be about 18 percent greater for two sources than for a sole source not counting potential competitive effects. (Because of the larger quantity, a learning penalty of only 12 percent would be implied for ASPJ under the same set of assumptions.) In other words, competition will have to yield savings of 18 percent plus an amount to offset the large cost penalties for codevelopment and non-recurring production in order to break even.

The V-22 program represents a new technology application that would seem to benefit from the involvement of two corporate design teams. But the relatively small quantity of aircraft involved (913) compared to other helicopter and fixed wing aircraft programs which often exceed 2,000 units makes it unlikely to overcome non-recurring cost and learning-curve penalties imposed by tow producers.

LHX

The Army LHX program seeks to develop a basic airframe with two variants—scout/attack and utility models which will be 70 percent common—to replace 12 existing helicopter types now in service. A requirement for about 5,000 helicopters exists with an estimated program cost of about $40 billion. The target unit production cost is $5 million.

The Army sought to encourage teaming through development for both



Right: An exploding M-47 Dragon missile

Far Right: The Dragon anti-tank weapon is shown as explosive devices warhead and rocket motors are integrated with the guidance unit at Raytheon's Huntsville Ala facility

Photos Courtesy of Raytheon

the airframe and the engine. Boeing Vertol and Sikorsky Aircraft agreed to team in June 1985 with McDonnell Douglas Helicopter Co. and Bell Helicopter Textron taking until this spring to agree. The teams are interesting in that they combine two manufacturers of large helicopters and two manufacturers of small helicopters to compete for the development of a small helicopter. This may have influenced the timing of the arrangements as Boeing and Sikorsky (the large helicopter firms) presumably had much less relevant technology to protect. The reluctance of Bell and McDonnell Douglas to team was apparently overriden by the Army's requirement for all respondents to the request for proposal to provide a plan for production competition following prototype production and the first two small quantity production lots.

The LHX airframe schedule originally called for a competitive 21-month development program to begin in August 1987 and culminate with the selection of the prototype to enter production in July 1989. But steadily increasing requirements during initial development have called into the question the feasibibility of a conventional helicopter. The program has now been put on hold while the RAND Corp. and The Institute for Defense Analysis study a tilt rotor alternative.

Avco Lycoming/Pratt & Whitney and Garrett Turbine Engine Co./Allison Gas Turbine Div. of General Motors were awarded competitive firm-fixed price contracts in 1985 for full-scale development of the LHX 1,200-shp engine. Each team received about $250 million. The winning engine contractor, to be chosen in mid 1988, will supply the engine as government-furnished equipment to the airframe manufacturer. Production of about 10,000 engines for $3.8 billion is projected.

AAWS-M

The new Army advanced anti-tank weapon system-medium (AAWS-M) required to replace the aging and inadequate M-47 Dragon anti-tank weapon is to result from a joint venture development team leading to production competition. The AAWS-M technology competition is between two categories of smart munitions. The first consists of true fire-and-forget systems with projectiles that seek their targets independently of the gunner. These include such weapons as the Tankbreaker focal plane array and a two-color infrared concept. The second category of munitions requires the gunner to do some of the guidance. These man-in-the-loop concepts for AAWS-M are the fiber optic guided missile and a laser beam-rider.

The first phase of the program will be a 24-month technology demonstration. It does not require teaming. However, teaming is required by the end of the technology competition, when the AAWS-M enters full-scale development. The two members of the final winning team will manufacture the first two produciton lots as a team, then compete against one another for subsequent contracts.

The new Army advanced anti-tank weapon system-medium (AAWS-M) required to replace the aging and inadequate M-47 Dragon anti-tank weapon is to result from a joint venture development team leading to production competition.

The Army had initially planned to require teaming from the outset. This resulted in problems as Texas Instruments and Hughes formed a team for the Tankbreaker alternative leaving Rockwell with no partner. Furthermore, the only beam rider competitors were Ford Aeronutronics and McDonnell Douglas; thus, there might have been only one team entered for that part of the competition. (McDonnell Douglas had also been funded for Tankbreaker work, but when the Army dictated that team members could be on only one team, a second McDonnell Douglas entry was eliminated.) This program, like the LHX airframe, indicates the difficulty of establishing teams in markets where there are verv few viable competitors.

ATF

The Air Force announced a new acquisition strategy for its Advanced Tactical Fighter (ATF) which calls for prototypes of two aircraft and two turbofan engines, as well as ground avionics demonstrators, to be built by 1990, two years earlier than originally planned. The stated purpose of the new schedule was to minimize the technical risks involved in the program and to reduce total program costs before the aircraft proceeds into full scale development.

Seven firms submitted proposals to become prime contractor for the ATF. But teams were formed as a result of a clear Air Force preference and budget constraints which will require contractors to share about 50 percent of the development cost. The two teams consist of: Northrop and McDonnell Douglas; and Lockheed, General Dynamics, and Boeing.

The Air Force is planning initial deployment of the ATF in the mid-1990s and hopes to obtain 750 aircraft at a unit price of $35 million. Projected program costs are $46 billion including $10 billion for research and development and $10 billion for spares, training and simulators.

The technological complexity of the ATF together with the fact that it and the Navy's Advanced Tactical Aircraft (ATA) are the only fighter programs planned for the foreseeable future support the formation of development teams to augment problem solving and to preserve the defense industrial base at the prime contractor level. But if the program evolves into production competition, it is probable that a very large cost penalty will be incurred due to the relatively small quantity planned and the high cost of duplicate airframe production capabilities.

Summary

All foreign codevelopment programs as well as foreign/U.S. codevelopment programs often face obstacles not found in U.S.-only programs. They include language differences, different measurement units (e.g., metric vs. English), different military specifications and production standards. However, the key difference for programs with foreign participation compared to U.S-only programs is the economic motivation to share development costs for a project that would be unaffordable if attempted by any of the participants singly and to maximize production quantity to lower unit costs. The U.S./foreign programs have typically been initiated here to gain new technology at a cost less than would be incurred by starting from scratch and to take advantage of existing products that could fulfill our requirements following modifictions and thereby avoid schedule and high cost penalties related to a new start. Certainly they also have a major political payoff related to giving credibility to the 'Two-way Street" objective.

Because production competition has not begun (as of this writing) for any of the cooperative development programs now underway, the following remarks are necessarily theoretical rather than empirically based. As such, they should be useful as strawmen for debate and as hypotheses to form the basis for empirical research and to provide a focal point for debate by acquisition policy-makers.

Issues to be Considered in Establishing Joint Development Teams

As shown above, collaborative developments transitioning to cooperative production could be judged successful based upon their individual objectives. Those objectives have been largely related to sharing development costs, transferring technology, maximizing production quantities and maintaining employment levels. They also demonstrate that independent firms can and have cooperated effectively. On the negative side, they have proved to be more costly in total and have taken longer than comparable development programs conducted by a single prime contractor.

The joint development approach being implemented for major U.S. weapon systems acquisition programs is the antithesis to that followed in international codevelopment programs. The U.S. government will most likely pay a greater total development cost (which will not be shared with another participating government) and greatly reduce, rather than increase, the quantity of units to be produced by a single source.

Although there is no federal policy mandating a joint development approach to new weapons systems acquisitions, the programs discussed above indicate that this procedure is rapidly becoming the rule rather than the exception without the support of either empirical evidence or cogent theory to suggest its eventual success as a cost saving measure. Rather, it appears likely that it will raise costs and lengthen program schedules. Support for this statement may be broken into three categories as follows: incentives to form teams, cost drivers for joint research and development programs, and effects on recurring production cost. Each is discussed below.

Incentives to Form Teams

Among all discussion concerning joint venture teams for the development of weapon systems, the legal implications have received little attention. Given the Reagan Administration's initiatives to restrict the application of antitrust laws, this could be a nonproblem. The Justice Department indicated that, as long as the firms involved in a joint research venture do not control more than 20 percent of the world market for their industry, it has little concern. It has expressed a willingness to entertain efficiency justifications for arrangements that lead to high market shares. Of course, a big issue would be how the "market" is defined for defense-related joint ventures.

Perhaps the key to successful joint venture teaming is the extent to which viable firms will cooperate. Logic should bound this problem. The bottom line is the bottom line as firms' willingness to cooperate with competitors will be largely a cost/benefit trade-off. Proprietary design data and manufacturing technology they would give and receive are important elements of this equation. Perceptions regarding the value of their data will be weighed against compromising it for the program at hand. Thus, the remaining useful economic life of the data for other applications, anticipated value of the program and technology benefits they expect to derive from their joint venture partner will be considered. Or it may simply boil down to the fact that failure to team would lead to economic ruin given a large, long-term program with a monopsonist dictating rules for participation. The joint venture teams formed (and not formed to date) support these assertions.

—The ITT/Westinghouse ASPJ team was said to have cooperated because the compromised technology would be obsolete by the time another major program started. This factor together with the large size of the INEWS program probably was responsible for the several teams formed for that competition as well.

—The Bell/Boeing Vertol V-22 team grew out of a NASA technology demonstrator program. The firms were both able to gain new technology while not cooperating with a direct competitor from their primary markets.

—The Boeing Vertol/Sikorsky LHX team involves two large helicopter manufacturers seeking government funding to enter a new market. The McDonnell Douglas/Bell team probably resulted from the stark realization that failure to join together would mean passing up the largest helicopter program in history.

—Again, the value of the ATF and ATA programs makes cooperation essential for any airframe manufacturer who wishes to stay in the combat aircraft business as a prime contractor. Several of the firms involved might be forced out of the fighter design business or demoted to a subcontractor role if they are not on the winning team for one of these programs.

Aside from technology concerns, it is probable that other identifiable considerations would be involved. They include:

—The compatibility of the two corporate cultures.

—The political clout that would result from connecting firms from different regions.

—Relative strengths in foreign markets when overseas sales are likely.

—Perceived cost profiles that would make prospective partners "beatable" during production competition.

Thus, it is reasonable to assume that "dream teams" conceived by the government may not materialize due to the many strategic concerns that would drive them apart. When a development teaming requirement is arbitrarily imposed upon an unwilling industry without commensurate rewards or penalties, the government may eliminate some better qualified firms from the competition thereby sowing seeds for a technically second rate product at too high a price.

Cost Drivers for Joint R&D Programs

The RDT&E costs are driven primarily by the extent to which existing technologies are "packaged" or new technologies which advance the state-of-the-art are required. A program for which much new technology must be developed would experience relatively large concept development and validation costs. Estimating the cost of these elements is fraught with uncertainty because it is impossible to specify how much effort is required to achieve a technological breakthrough.

Estimating precisely what any research and development program should cost is difficult, but it is relatively certain that joint programs will take longer and cost more—all else being equal—because of the added coordination involved and the necessarily overlapping responsibilities. Even when each firm is given discrete design responsibilities, significant coordination is required to assure that interfaces are effective and that producibility is assured for the nondeveloper. It is not unreasonable to assume that the development process will be "gamed" to the extent possible to exploit the developer's manufacturing strengths and/or the partner's perceived weaknesses.

It is a virtual certainty that the need to coordinate the oversight of two developers will require additional government program management personnel. The amount of the increase is not known, however, and could not be realistically estimated for the general case. A functional breakdown would be required to estimate it for a particular case. For example, it would be reasonable to assume that time spent negotiating contracts would approximately double; however, time spent in design reviews would increase to a lesser extent. A key issue would be the degree to which the government was called upon to adjudicate contractor disagreements.

Pilot production is a major cost driver for RDT&E programs as it depends primarily on the number of prototypes involved. Each firm would need to produce enough to gain experience and understand likely problems in transitioning to hard tooling. However, the extent to which this quantity would fall within or beyond the quantity required for testing is inestimable for the general case.

On the positive side, the potential synergism resulting from two disparate viewpoints working on problems may lead to earlier and more desirable solutions and thereby achieve savings in some aspects of the program when complex technical solutions are required. Of course, a fully integrated development team could take on a homogeneous character that would tend to deemphasize diverse approaches to problem solving.

Experience indicates that joint-development program costs will be greater than sole-source development program costs; however, it is impossible to provide a useful rule-of-thumb for the amount of increase.

Recurring Production Effects

Dual-source production competition has often increased costs in comparison with estimated costs for a sole source. This will not be a problem for joint-venture teams as no sole-source experience will exist to serve as a baseline estimate. Nevertheless, differences between joint technology development and technology transfer provide a basis for making reasonable assumptions regarding the effects of a

codeveloper compared to another type of second source on production competition.

When dual-source competition has been successful in reducing estimated recurring production costs, several factors have been credited, some of which would not be likely to occur under joint-development teaming. For example, the second source typically gains significant learning through the technology transfer process (e.g., a data package and technical assistance from the developer) that enables it to achieve a first unit cost significantly below that of the initial source. However, the second source is still often at a disadvantage when the initial firm has a large head start with respect to quantity produced. Although joint-venture teams would eliminate that learning disadvantage, it is not clear that both producers would start at a lower than "normal" first unit cost. If a sole-source learning curve were duplicated, costs would be greater than for a sole source because learning would not be optimized.

Another important point is that cost savings have sometimes resulted from the second source bidding naively low because it did not understand the true nature of the item and problems associated with producing it. Under joint-venture development teams it is reasonable to assume that complete information would eliminate this factor. On the other hand, a "skimming" strategy whereby the initial source would bid higher than normal before advent of competition due to an assumed disadvantage on the part of the second source would be eliminated.

Conclusions

Two sets of circumstances are likely to bring about the formation of development teams: economic advantage and economic necessity. Economic advantage will arise when firms complement each other in such a way that perceived long-term benefits outweigh the drawbacks of sharing proprietary d.ta and merging problem solving capabilities. The formation of such teams is purely voluntary like those represented in the electronic warfare programs described. Teaming will result from economic programs described. Teaming will also result from economic necessity such as a government requirement for teaming on a program of such magnitude and importance that failure to participate may lead to a significantly reduced long-term role in a particular industry. The LHX and new fighter aircraft programs will cause the creation of teams out of economic necessity.

Once formed, it is not clear that the initial motivation for teaming will cause their members to perform with different levels of effectiveness. It is clear, however, that major progams may make teaming mandatory in order to preserve the defense industrial base, especially its technological innovativeness. From this standpoint, it makes sound policy sense because leader/follower production programs have provided strong incentives to be an efficient producer at the expense of discouraging technological advancement. But, anticipated benefits should be measured against estimated costs. There is no reason to assume that savings will result from joint-venture development teams with competitive production. On the contrary, higher costs should normally be anticipated because of the redundancy required throughout the acquisition process.

Given a case with a large enough quantity requirement to offset significantly greater RDT&E and nonrecurring production costs, and two firms with appropriate experience and capabilities for the required item that are willing to share knowledge and expertise during development and able to compete during production, this systems acquisition strategy may be feasible or even desirable. However, its implementation should be based upon sound identification and analysis of relevant issues and not because of some vauge notion that it is "the way to go" in order to achieve cost savings. Unfortunately, the programs to which this strategy is currently (as of this writing) being applied offer no evidence that it is being selectively applied based upon a careful assessment of estimated costs and benefits. ■

A-6 Intruder
Photo Courtesy of Grumman

COST

HOW TO ACHIEVE A COMPETITIVE EDGE IN PRODUCTION

Troy V. Caver, PE

The present method of estimating and then negotiating cost in government production programs involves considerable application of the cost improvement curve. This curve originally was called the learning curve but in production today only about 6-10 percent of value added is from labor hours. Hence, this article's perspective is: There are many causes for cost reduction other than improvements from labor familiarity.

The learning curve has been defined since 1936 as a means of determining cost based on cumulative numbers of items produced. Essentially, cost is derived by an equation that is $Y = A x^b$ (Figure 1):[1]

This required that A be entered as the first unit cost; x be shown as the specific production item to be costed; and "b" represent the log of the improvement factor divided by the log of 2 (due to the doubling rule).

The common belief is that this cost improvement resulted from worker learning; consequently, the curve was called "learning curve." More recently, we see the curve influenced considerably by changes in the rate of production, which made addition of a second curve for economies of scale appropriate. John (Jack) Bemis, government employee at the Defense Production Engineer Services Office (DPESO) in 1978-80 developed a computer model allocating the cost for economy of scale changes to the annual program production.[2]

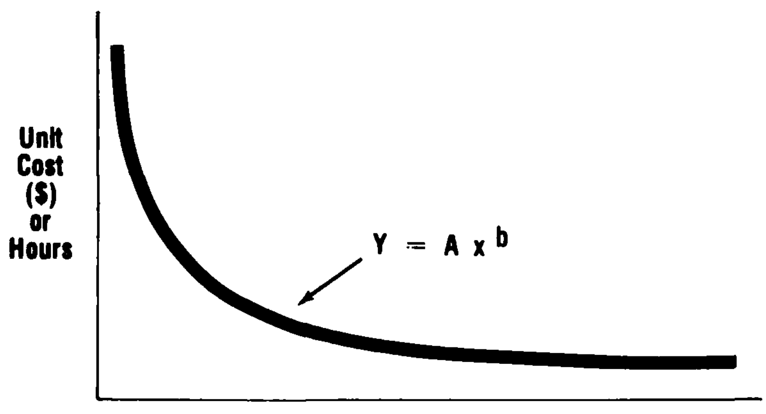
The equation describing the 3-D surface which it forms is:
$Y_t = A\ Q_t^b\ R_t^c$ (Figure 2):

Bemis obtained cost data from more than 20 production programs to examine cost changes at different rates of production; also, to develop a pattern of predictable influences enabling development of his model. He didn't specify programs by name but his data and the goodness of fit is shown at Table 1. By using a separate slope for rate and cumulative quantity, Bemis got a curve fit of better than 96 percent for each program examined. This level of accuracy then permits use of the curve parameters for extrapolating cost impact for budget or rate change with greater confidence. While that model was used in the government for examining cost impact of rate changes in DOD production, it was not distributed to, or used by, the industry in general.

More recently, cost improvements from competition, technology injection, labor training, management emphasis on cost reductions, redesign for ease of assembly, and other actions demonstrated that cost reductions are more than labor learning or economies or scale.

Normally, it would be expected that to split the buy of a quantity of items would yield a higher cost as both companies would have lower cumulative production; hence, a loss of benefit from potential cost improvements of the learning curve.[3] This was expressed by Michael Spence in *The Bell Journal of Economics*[4] and is the prevailing thought on learning curve application. Experience from competi-

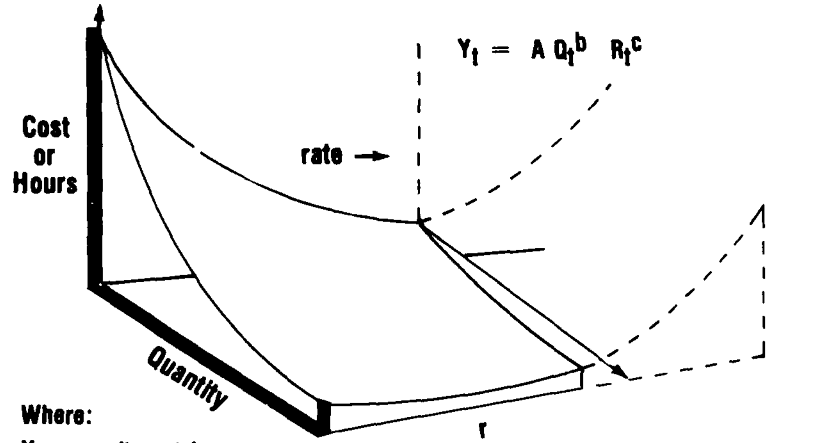
Figure 1. Theoretical Shape of the Cost Improvement Curve



Where: Y = unit cost
A = first (prime) article unit cost
x = unit number (i.e., 12th item) being produced
b = the experience curve exponent

This article summarizes doctoral research being conducted by the author. It examines contributions to cost during production. Mr. Caver does not propose an assured route to success, but he points out attributes influencing cost during periods of new product start-up, rate production, and production phase down. He proposes that a production firm's management aware of these cost impacts act appropriately to reduce production costs leading to better cost competitiveness.

Figure 2. Theoretical Shape of the Cost Surface Reflecting Quantity and Rate



Where:

Y_t = unit cost in year t
A = prime or first unit cost
Q_t = cumulative quantity
+b = quantity exponent for describing the slope as log (progress rate)/log (2)
R_t = quantity effected by the present rate structure
+c = the exponent describing the slope of the rate/cost curve and which represents the economy of scale cost impacts for the items produced at the present rate

Table 1. Bemis Production Slope Parameters

System	Multiple Regression R	Multiple Regression Rate Slope	Multiple Regression Quantity Slope	Individual Regressions Rate R	Individual Regressions Rate Slope	Individual Regressions Quantity R	Individual Regressions Quantity Slope
Aircraft A	.974	97.5	73.1	—.737	71.4	—.974	72.1
Aircraft B	.948	(4)	77.2	—.923	78.6	—.961	87.7
Aircraft C	.995	79.5	87.3	—.958	68.5	—.936	76.0
Aircraft D	.923	68.0	88.2	—.877	61.6	—.706	76.9
Aircraft E	.997	67.2	90.5	—.996	58.7	—.992	67.8
Aircraft F	.994	57.3	86.6	—.972	52.8	—.679	67.0
Aircraft G	.999	81.4	84.0	—.986	58.7	—.994	75.8
Aircraft H	.971	91.4	74.4	—.815	66.7	—.964	70.7
Aircraft I	.999	(5)	86.3	—.972	80.0	—.999	87.7
Aircraft J	.786	86.3	97.1	—.768	89.5	—.542	94.8
Helicopter	.997	89.3	83.8	—.875	81.9	—.996	83.1
Jet Engine A	.984	92.0	75.0	—.652	74.6	—.971	72.6
Jet Engine B	.988	89.5	71.4	—.477	76.3	—.970	69.8
Missile A	.974	(6)	65.1	—.925	52.5	—.974	66.0
Missile B	.873	(7)	82.3	—.463	84.2	—.851	85.4
Missile G&C	.981	90.7	(1)	—.820	89.4	+.684	(1)
Missile G&C	.996	59.4	91.9	—.990	62.8	—.820	60.0
Ordnance A	.964	97.0	88.1	—.622	93.2	—.932	86.6
Ordnance B	.978	(3)	97.5	+.588	(3)	—.972	76.6
Radar A	.990	88.8	93.1	—.902	86.0	—.765	87.7
Radar B	.890	91.6	98.9	—.870	88.8	—.784	94.7
Tracked Veh	.963	90.7	(2)	—.867	88.7	+.700	(2)

Where R = correlation coefficient

(1)--(8) Slopes greater than 100 percent

tion in government, however, shows when competition is injected, the resulting price of each competing company is usually lower, often as much as 20-25 percent. Additionally, the cost improvement curve tends to steepen 5-10 percent *after injecting competition* (Figure 3). At this point it may be important to relay to you that if a 5 percent improvement could be made in the cost improvement curve from the beginning it would represent approximately 40 percent improvement in the cumulative cost during the life of a program![6]

Observations of Competitions Effect on Cost-Improvement Curve

Some argue that the lower *price* to the government doesn't necessarily mean a lower cost to the manufacturer. We must recognize that *sustained* reduction in price implies that cost improvements were actually there.

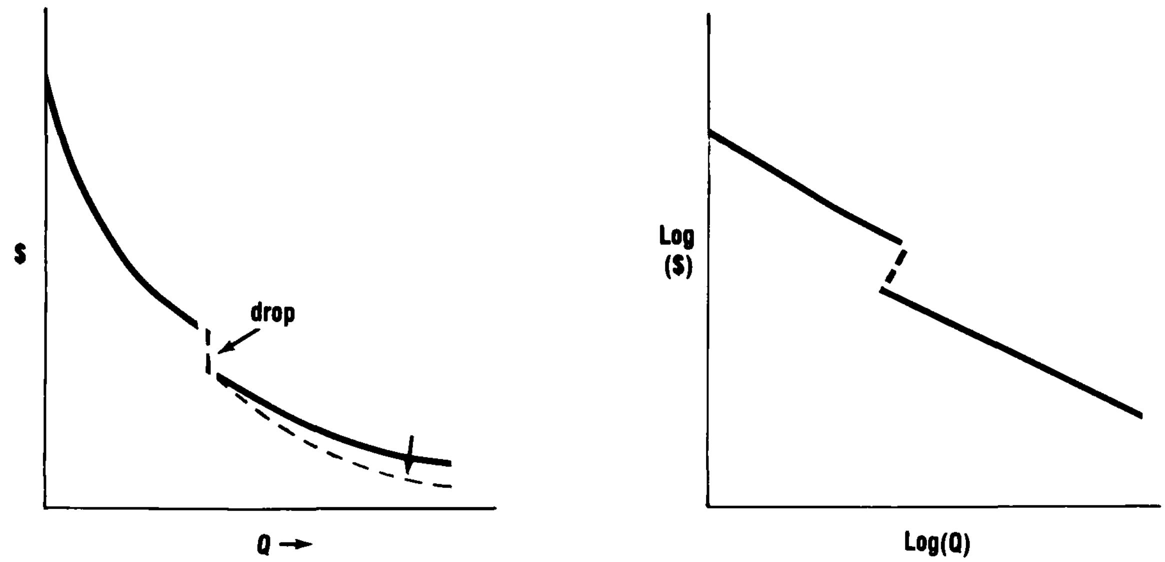
Examples of How It Can Be Done

As a measure of the influence management may have, one aerospace company reported that when management was personally involved and made cost reduction of production items a measure of the manager's bonus, the cost improvement rate improved dramatically, from 84 percent to 64 percent. Most of these improvements resulted from design engineers working *on the production floor* for an extended period after starting production. When bottlenecks were identified, design engineers, manufacturing engineers, quality engineers, and process operators examined the problem and identified multiple fixes. Engineers found many materials and tolerances were identified too stringently; when they fell off the tight requirements cost dropped dramatically without sacrificing quality. Achieving improvements of 84 percent to 64 percent in the cost curve meant a 75 percent reduction in unit cost.

A second recent example was provided from a manufacturer of electronic munitions for the government. These munitions were of varying complexity and, in some cases, included

■ *Mr. Caver is a Professor of engineering management at the Defense Systems Management College.*

Figure 3. Observations of Competitions Effect on Cost-Improvement Curve



components as well as the assembly of the major munitions. Market share had normally been determined by an annual fixed price contract award among competitors. Bids were taken and typical awards were 60/40 percent or 50/50 percent splits. This particular company, (Company X) which took an action to change that market share, was a designer as well as producer of the munition. In a recent annual rebid, Company X realized that while it had the lowest bid and got a 60 percent share of the total buy, the competitor (Company Y) had so aggressively lowered its actual cost that Company X realized its own rate of cost improvement would be overtaken the next year by Company Y. Company X feared that the competitor would not only get a larger share (60 percent) but might garner a full 100 percent of the buy. Should this happen, the embarrassment of Company X would be that it designed and got the initial production contract but couldn't control cost as well as an outsider.

Company X totally evaluated the design and processes for building the munition. Some actions taken: (See Figure 3a)

The next year's bid was more aggressive than would have been possible (25 percent less per item than the previous year) and resulted in a 100 percent award of the available production, while yielding a greater profit than in any previous year.

Figure 3a. Actions Taken by Company X

Make—Buy	Totally revised
Plant Lay Out	Rerouted for more efficient flow
Inventory Method	Just In Time initiated
Subassembly Procedures	More efficient methods adopted
New Communications	Improved communitions with employees
Management Talked	Potential loss of contracts and jobs was emphasized
Management Listened	Employees were asked for ideas on how to operate processes and assemble more efficiently
Management Acted	Review committees examined each employee suggestion

The results of these actions yielded:

Labor hours per unit	Reduced by 50 percent
Rework Reduced	From 30 people required to 4 (which was then further reduced)
Inventory Reduction	Eliminated materials handling personnel as well as assets tied up in inventory
Reduced Scrap	Material savings
Procurement Savings	Personnel had time to do more value analysis

The common thread of these two companies and others reporting data to me is they took an action when threatened. This implies the cost improvements can be obtained, but it is white-collar management that must understand enough about design and production functions to know *how* to act to obtain it. Too often we avoid conflicts associated with the cost-reduction effort by taking an "if it ain't broke, don't fix it" position.

Costs are also reduced by production process improvements. Many films have been made showing reduction in cost resulting from government/industry participation in the Industrial Modernization Improvement Program (IMIP). In one of many examples, a company adopted an abrasive water jet as a cutting tool for tungsten, reducing the cost of materials by 50 percent.

Rate of Improvement Is Not Consistent

Most production programs have a pattern of cost reduction that starts slowly; then, cost reduction rate steepens for a longer period as production approaches the planned rate; then, near the end of production, the cost reduction rate ceases to continue its drop. Some examples follow (Figure 4):

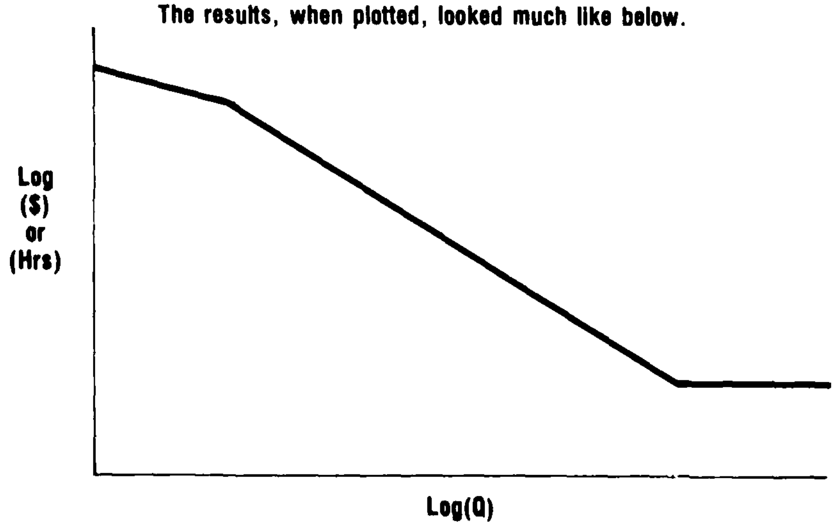
Stanford Research Institute discovered this inconsistent slope of the start-up portion of the curve to be true in the early 1940s, describing the curve as a backward S curve with the entry point defined based on the experience of the producing company. Companies with much experience started at a lower point. They suggested "Beta" values for describing the entry level. Major Doug Fisher wrote that he identified this three-phase pattern in Air Force programs with some degree of regularity. He pointed out the range of cost improvement slope for each of the phases with data from several programs to support his observation.

The effects of production planning are shown in the following. A report on producibility based on a government/industry study[5] showed a trend of first unit price and learning curve slope dependent on the amount of producibility engineering and planning conducted before production began. The programs with early emphasis on designing for producibility realized an average first unit cost savings of 15 percent. Those without such planning incurred an additional 13.6 percent cost. One conclusion was programs entering with a high cost had a steeper improvement curve; those with a lower first unit cost had a more gentle rate of improvement.

Figure 4. Shape of Typical Cost Improvement Curve During the Life of a Program

	Initial LC Slope	Improved LC Slope	Units Before Change
F111	85%	75%	40
B58	80%	67%	10
C-5	89%	61%	8
F106	81%	54%	18

The results, when plotted, looked much like below.



New Theory

A new theory, which I trust you will share with me as logical, is that the cost improvement curve is dependent on far more than the number of items produced. I believe that:

Ho- The cost improvement curve start point, usually referred to as T-1, is influenced by the quality of the technical data package (TDP) and the planning accomplished for production.

H1- The rate of cost reduction, which is represented by the cost improvement curve, changes with the opportunity and management emphasis to identify errors in the TDP and manufacturing processes, and the potential for cost reduction at a higher rate is greater for systems that start production with technical data packages that are incomplete, full of errors or not well developed.

This is best understood when you realize the production team is looking to the technical data package as an instruction set for doing the production job. If the instructions are incomplete or in error, laborers on the production floor must stop to fix the error, or attempt to work around the stated instructions and make items the best way possible. The more errors that are in a TDP, the faster and easier they can be identified and corrected. Each correction reduces time and cost for successive items produced, which is represented by the downward slope of the cost improvement curve.

H2- The cost content while measured in labor or materials typically reflects the actions of the product designer, operations on the shop floor and the many actions taken by the manufacturing organization and senior-level managers to make the product cost-effective.

Information collected shows that most production programs have a pattern of cost reduction that has been slower initially, then steepens for a longer period. Near the end of the programs rate production, events occur that result in a lessening of cost reduction rate. This is often called the "toe-up" period. It appears that the mathematical representation of these findings are represented by the formula on the next page in Figure 4a where each of the X, subscript n, terms above represents a period of production with a different set of circumstances for cost ac-

Figure 4a. Each Phase Has Different Properties

$$\text{TOTAL COST} = \sum_{i=1}^{P_1} AX_i^{b_1} R^{c_1} + \sum_{i=P_1+1}^{P_2} \left[\begin{array}{c}\text{COST OF}\\ \text{LAST ITEM}\\ \text{FROM PRIOR}\\ \text{PHASE}\end{array}\right] X_i^{b_2} R^{c_2} + \sum_{i=P_2-1}^{P_3} \left[\begin{array}{c}\text{COST OF}\\ \text{LAST ITEM}\\ \text{FROM PRIOR}\\ \text{PHASE}\end{array}\right] X_i^{b_3} R^{c_3}$$

This equation represents the sum of unit costs of items in Phase 1 of the three production phases. Rate R changes with facility loading.

This equation represents the sum of unit costs in Phase 2 with the first item being the last item of the previous page.

This equation represents the sum of unit costs during the toe-up phase.

cumulation than that during other periods. The exponent for each period will be developed as a result of the actions taken before production to design and plan for efficient operations and, during production, to motivate those implementing the plan to find ways of reducing cost. The open bracket beginning each term represents the cost of the last item produced under the previous phase. The number of items produced during each phase is defined by the user of the model; cumulative cost is summation of the cost of all items in each phase added to the cost of items in each successive phase. The R value represents the economy-of-scale contribution for each production phase and, hence, has its own exponent. If the production phases represented one year, the X_i and the R would represent the same period and therefore would be the same number.

The early flat period of the curve and the mathematical representation is concerned principally with getting the plant and processes operating, and getting the first items produced. Therefore, the major effort is improving the efficiency of the plant, processes, and ability to understand technical data. Likewise, during the second major portion of the cost-curve reduction, the effort is to find material, specifications, and process improvements yielding labor and machine time reductions. The last phase or "toe-up" represents shifting emphasis to other than cost reduction; i.e., reassigning key people, efficiencies lost on machine loading and on plant and people utilization, staff allocation charges not cost effective.

What is lacking is a method to identify quickly a method to calibrate each phase to understand weighting of contributors to influence cost reduction. It is probable that this can be done only with data from many programs with multiple regression analysis of power functions separated by phases.

Importance of Knowing

The following phone call in December 1986 is a personal example of what is happening. The caller represented an Air Force plant representative (AFPRO) responsible for inspecting and overseeing production acceptance of an item from a major aircraft manufacturer. The manufacturer wanted to negotiate the allowable cost reimbursement of the first unit and succeeding units based on his negotiated cost improvement curve. The DCAS had negotiated a cost improvement curve of 84 percent. The contractor said his history of production was to hit standard at item 3000. Therefore, he wanted to use item 3000 as a standard and, using the 84 percent cost improvement curve, negotiate that he would be paid progress payments and other allowable costs based on a first unit cost of 17 times standard. (Standard is the expected cost of an item made according to plans by the average well-trained workers.) The AFPRO asked: "Is this a legitimate way to determine allowable cost?" My response was that it not only sounded wrong; it sounded fraudulent. The AFPRO later called to say his DCAS regional office advised using the proposed methodology as it had no better method.

On the other hand, had the contractor used the tools of technology improvement that would allow the elimination of most bottlenecks and provide for a much lower first unit cost, the government attitude about the learning curve application would almost certainly have required that he demonstrate the same slope of cost improvement, in this case 84 percent, that he had always achieved. If errors were reduced in the planning, it would be more difficult to achieve the same rate of "finding and fixing" the fewer remaining design errors; hence, a flatter curve would be expected.

When you realize that the 1986 cost of procurement programs alone exceeded $150 billion, I suspect that "not having a better way" is costing either the government or the contractor millions of dollars each day—in contracting alone. In my example, it appears the contractor recognized consequences of having to attain a curve he previously worked to; and, perhaps, gamed it in such a way that he used the government's rigidity (an 84 percent curve) to take the pressure off him during production by negotiating a higher start point. What a price we pay for not pressing for acquisition research!

While I mentioned earlier that a 5 percent improvement in the slope of the cost improvement curve will improve the cumulative cost of a project 40 percent, it is important to know that the many items mentioned so far make the cost improvement curve dynamic, especially in the early years when it is getting cost reductions from more than technology improvements. Since the past procedure for cost estimating and negotiation have been for a single value of a cost improvement curve (and we can now see many of the different contributors that shape the curve), it is necessary to alert senior management when it is about to make a change that will adversely impact cost reduction opportunities.

For instance, in the government, an annual ritual occurs with each budget submit, and again when the budget is going through the wickets in the Congress. The question is always passed to the programs with production funding asking: "What is the impact if we reduce your budget or stretch out your production quantities in the next budget year?" The question is usually phoned to the program without warning and often the program manager is away.

A response is requested to modify the budget request which is *already* in the Congress. The answer you give must be reasonable and must represent the program's actual cost required; otherwise, you will be forced to operate with an unsatisfactory budget. The response is often required within 1-2 hours, leaving no time to query the contractor to confirm the soundness of the numbers.

The program manager must, in most cases, sacrifice something in his program to continue operating with reduced funding. If he gives up funds programmed as planning for producibility, he should know the extra cost impact. If he gives up automation on a particular function, he should know the impact and how to calculate it in cash-flow needs of other funds. Results of this ongoing research will assist in determining the impact of proposed budget reductions, or proposed quantity changes, *before* funds are removed.

Additionally, when a program is being structured, there are areas that may be funded that provide different levels of return on the investment. What is the return on a specific production technology? What is the expected benefit of using a computer-aided design? Should the company use its next $1 million to purchase computer design tools or to train management to use systems engineering?

Results of this research will provide guidance on marginal return for the next incremental investment toward cost reduction of the program under analysis. Using a finished model like the one expected to result from this research will aid in decision-making before commitment; aid in negotiations during contracting, and indicate where greatest value-added opportunities are during production. Should the government change the funding or rate of production, there will be a common tool for computing the reasonable cost changes. Also for the contractor, using such a model will provide opportunity to examine the greatest pay-off for marginal dollars available for cost reduction.

The Design-to-Cost policy now being imposed throughout DOD contracts is intended to provide the management attention needed to achieve the cost reductions. Allocation of cost design goals from systems engineering down to design engineering must be accomplished in full-scale development. This requires further technical budgeting down to subassemblies and, finally, piece parts. Design-to-Cost goals include not only traditional make-buy decisions but scrap rates, test hours, work in process inventory reduction, and all other cost components. Records of the progress toward cost goals must then be maintained and barriers to cost reduction quickly identified and eliminated. This scope of effort requires that not only design and production engineers sign up and work their goals, but the entire team must take ownership of the cost goal.

Need for Continued Research

The data in this article result from my ongoing research.

While recognizing that cost improvement curves are not a fixed slope may sound logical to the average reader, it is a far cry from what industry and government have believed and used for the past 50 years. Using fixed cost-improvement curves makes up such a large part of our cost negotiating structure that single 1 percent improvements may be the basis of several weeks of negotiating. What is rarely negotiated, however, is the first unit cost or the production unit at which the organization will attain the calculated cost standard.

Negotiating an improvement slope without a first unit cost specified, or without specifying the production unit at which standard is to be achieved, leaves the resulting cumulative cost wide open. Using today's procedure, the government makes little or no accommodations for technological improvements in computer-aided design or computer-aided manufacturing; or the use of computer-aided inventory and scheduling procedures developed in the past 10 years. A book and computer model, *Designing for Ease of Assembly*, by two professors at the University of Rhode Island, points out that where design for ease of assembly techniques have been used, material and labor reductions of 30-50 percent have been realized. Yet, present procedures to implement change in government contracting are driven more by congressional mandates (70 percent of the FAR was changed as a result of the '84 procurement law changes) and very little from technological change. I fear our recognition of cost content will need the Japanese to act first, showing it *can be done* on a big scale; then, U.S. industry will have to scramble to recover lost markets.

Research is now being directed toward identifying contributors to cost reduction; then, toward the period when these contributors will influence cost reduction the most.

Any company involved in design and production wishing to get more information, and eventually a copy of the completed software model, may contact me at the Defense Systems Management College, SE-T, Fort Belvoir, Va. 22060-5426.■

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The People's Republic of China

An Awakening Giant

Article and photographs
by
David D. Acker

China is a nation on the move. It is making noticeable progress in improving the economy, the living conditions of its people, and its place among nations. Anyone who steps behind the scenes usually seen by tourists can readily observe improvements in living conditions. New construction, residential and commercial, is visible everywhere; food appears to be abundant; department stores are well-stocked; and the people display a general mood of optimism.

Changes taking place in China are causing Americans to be favorably inclined toward forging links with the Chinese. Links are being formed as a result of the increase in American tourists, academic and technical exchanges, joint ventures — about 2,300 with foreign companies now — and official government exchanges. Under Deng Xiaoping, 82, former government leader, and Zhao Ziyang, secretary general, the country has been experimenting with market mechanisms, consumer orientation, private ownership, and incentives. Quite a change!

The seventh Five-Year Plan (1986-1990) is expected to generate an annual rise in incomes of about 7 percent, an increase in new capital construction of about 31 percent, and a large increase in food production. Foreign investments will be used to effect technology transfers and improvement of managerial skills. China will strive to export consumer goods, rather than import them.

This part of my report focuses on engineering education, engineering research, industry, and defense.

This is the second of a three-part report on the People's Republic of China today. The first appeared in the November/December 1987 issue of **Program Manager** *and the last will appear in the March/April issue.*

工程師角色

ROLE OF ENGINEERING

At this time, the future direction of engineering in China seems uncertain. Engineering, like many other activities, will be strongly dependent on the political and ideological course China takes in the years ahead. History reveals that China has made outstanding engineering contributions to the world in the past; i.e., the compass, gunpowder, paper, porcelain, and silk cloth. Perhaps its deep commitment to the Four Modernizations (Figure 1) will bring about the economic development and technological advances that are needed today. Unfortunately, some constraints on such development and advances exist because China doesn't have the strong financial base required for extensive capital investment. Further, the number of engineers and trained technical personnel is not sufficient to meet the needs China recognizes today.

The period from the late 1980s to the year 2000 will be crucial for the Chinese — a period of great challenge. There are bound to be problems and setbacks, such as problems that were caused by the Cultural Revolution. However, it is conceivable that the ingenuity and entrepreneurship of the Chinese people will be an invaluable asset in their drive to achieve technological modernization. Let's look at what is taking place in China relative to engineering education and research.

Figure 1
Four Modernizations

AGRICULTURE
INDUSTRY
SCIENCE AND TECHNOLOGY
DEFENSE

工程師教育

ENGINEERING EDUCATION

If China is to realize the Four Modernizations by the year 2000, it must develop more high-quality engineers and technical personnel in the next few years. Engineering education, therefore, will have a critical role to play. Today there are 271 schools of higher learning devoted to science and engineering. An additional 45 colleges and universities have engineering and science departments.

Of the 11,760 courses taught in Chinese schools of higher learning today, more than 3,750 are in engineering and more than 880 are in sciences. To carry out this task there are more than 344,000 university teachers, including 96,000 engineering teachers and almost 80,000 science teachers.

Before 1949, Chinese higher education was greatly influenced by American skills and practices. Many of the best Chinese engineering students studied in the United States and, upon their return to China, assumed influential positions. During the early years of the People's Republic of China (PRC), the Sino-Soviet cooperation had a major influence on the education of engineers. Many Chinese engineering students went to Russia for their courses and many engineering colleges in China patterned their educational programs after the Russian educational system. In 1947, there were only 207 schools of higher learning and the areas of specilization were narrowly based. Also, at that time, there were about 37,500 undergraduates and 425 graduate students majoring in engineering and science. The schools were concentrating on teaching and little time was spent on engineering research.

Between 1949 and 1986, China graduated 1.75 million engineering students and 359,000 science students. During the same period, 42,500 engineering students and 21,000 science students received advanced degrees.

The Cultural Revolution, which started in the 1960s, nearly destroyed higher education in China. However, following the downfall of the Gang of Four (Mao's wife and three Cultural Revolution-era associates) in 1976, an accelerated program of engineering exchange was established with the West and it has resulted in a new era in Chinese engineering education.

Present Chinese educational institutions fall into three types of governmental administrative jurisdictions. The Ministry of Education sets overall policy and coordinates such common functions for the institutions as establishment of national and regional standards, preparation of entrance examinations, and development of curricula. Many institutions are administered by industrial ministries. A majority of the engineering universities/colleges are under direct jurisdiction of provincial and municipal governments.

ZHAO ZIYANG

Although Chinese universities/colleges do not grant academic degrees, students are required to complete a rigorous program of instruction before they are eligible for graduation. The engineering courses represent typical Western practice. The university/college year is normally 40 to 45 weeks in length. The courses consist of 20 percent common core courses, 20 percent basic science courses, 35 percent basic engineering courses (materials, mechanics, thermodynamics, fluid mechanics, machine design, electronics) and 25 percent specialized courses such as manufacturing technology.

In 1977, there were only 450 full-fledged institutions of higher education. Recognizing a need, Chinese leadership launched a crash program to develop more colleges, universities, and technical schools. Now, there are more than 700 colleges and universities with an enrollment exceeding 1.2 million and more than 3,000 technical schools with an enrollment exceeding 1.3 million. Of this number, 80 are major universities and 40 offer graduate programs.

Since 1978, entrance examinations have been the primary (and usually only) factor in determining admission to universities/colleges and technical schools. Examinations are rigorous and only about 8,500 graduates are accepted for further formal education.

Until 1979, most universities/colleges had a full program of required courses for each of the four years. Since then, most universities/colleges have reduced the number of required courses in the third and fourth years and have offered elective courses to increase student interest. Presently, about 30 percent of the university/college courses are electives.

Graduate education, suspended in 1965, was reintroduced in 1978. Since then, more than 40,000 students have been admitted to graduate programs. There are three ways students may be admitted to these programs: (1) by university departments; (2) by the Graduate Academy or the research institutes composing the Chinese Academy of Sciences, or (3) by the Academy of Social Sciences. Graduate courses usually focus on the student's special fields of interest.

Mr. Acker is a Professor of Management at the Defense Systems Management College.

DENG XIAOPING

During the 1980s, much discussion and debate has been devoted to such conflicting demands as quantity versus quality in engineering education, general versus specialized education, basic engineering versus applied engineering, teaching versus research. Competition among engineers for educational and research funds is growing as is competition for good positions in industry. This is a stimulating and challenging period for China's engineering education community.

Four Chinese engineering institutions in which I had an opportunity to meet with management and faculty members are discussed below.

Beijing Institute of Technology. The Beijing Institute of Technology grew out of the Yanan Academy of Natural Sciences. The Academy, founded in August 1940, had as its aim the training of scientists and engineers for the creative and independent work needed to support the war effort. Graduates played an important role in improving the people's living standards and supporting the resistance against Japan. In 1949, after merging with other colleges, the Academy moved to Beijing. It was given its present name in 1951.

Today, the Beijing Institute of Technology is a comprehensive educational institution with science, engineering, management and liberal arts faculties. It has a computer center, a multi-media educational center, a machine shop, an electronics shop, and an optical workshop.

There are nearly 1,400 faculty members, including 600 professors and associate professors, and 800 lecturers, as well as a large number of engineers and technicians working in 60 laboratories. The 16 departments offer 766 courses and 33 specialties. Through its 20 research organizations, the institute has delved into locomotive engineering, mechanical engineering, chemical engineering, applied optics, radar, and explosive and safety techniques. Recently, it added such new disciplines as materials science, photoelectric technology, and robotics.

The institute has an enrollment of 6,000 undergraduate students and 1,300 graduate students. The graduate school offers master's degrees in 37 specialties and doctorates in 11 specialties. The institute operates 63 correspondence centers in 17 provinces and municipalities throughout China. In the past 47 years, 30,000 students have graduated from the Beijing Institute of Technology.

Northeast University of Technology (NEUT). The NEUT, situated in the southern part of the city of Shenyang on the Hun River, was established in 1949. It was formed from what had been the Shenyang *Engineering* Institute. Renamed Northeast University of Technology in 1950, it has developed into a university offering engineering, sciences, liberal arts, management, and other disciplines.

The NEUT, under the Ministry of Metallurgical Industry, is one of the national institutions. This university has responsibility for educating advanced students in the areas of engineering technology, scientific research, and management engineering. It also conducts research projects for the state.

The university is composed of 19 departments, which offer 29 specialties, and eight research institutes. Students may enroll in one or more of the following academic programs: a four-year bachelor's degree; a two-and-one-half year master's degree, or a five-year doctor's degree; For non-degree students, a two- or three-year training program is offered. The NEUT offers evening courses and correspondence courses, and has a branch college. There are 4,018 faculty and staff members, 560 postgraduate students and 5,266 undergraduate students.

During the past three decades, the NEUT has succeeded in educating a large number of Chinese students and many students from other nations. There have been approximately 33,000 undergraduate students, 400 graduate students, 1,500 correspondence and part-time students, and 100 foreign graduate and undergraduate students, including those who took refresher courses, from eight foreign countries.

Between 1978 and 1983, NEUT completed 259 scientific research projects. Of those projects, 235 won research prizes.

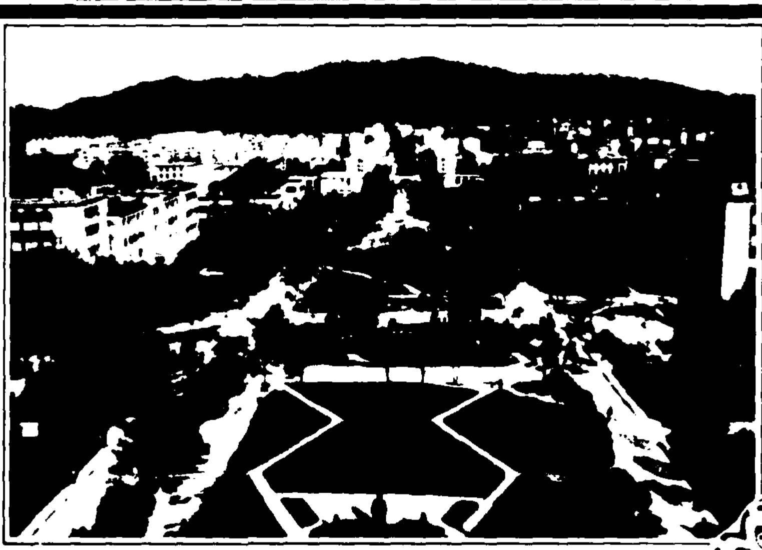
Zeijiang University. This university is located in the garden city of Hangzhou at the foot of Laohe Hill and close to beautiful West Lake. Founded in 1897, it is one of China's key universities under the State Commission of Education.

Zeijiang University offers courses in science and engineering and other fields. The university has 18 departments and a graduate school, seven research institutes, a central laboratory (including a computer center), and five university-operated factories.

Total enrollment for this academic year is almost 11,000. More than 9,000 are undergraduates, and more than 1,500 are graduate students seeking masters or doctors degrees. There are 2,350 teachers on the faculty — more than 600 are professors and associate professors, and more than 1,700 are lecturers and assistants. In the library, there are more than 100 staff members, 55 percent with university degrees.

The library provides 2,300 seats in six reading rooms and has more than a million books and about 9,000 periodicals published in Chinese and foreign languages.

Main Building Northeast University of Technology Shenyang



Zeijiang University Campus Hangzhou

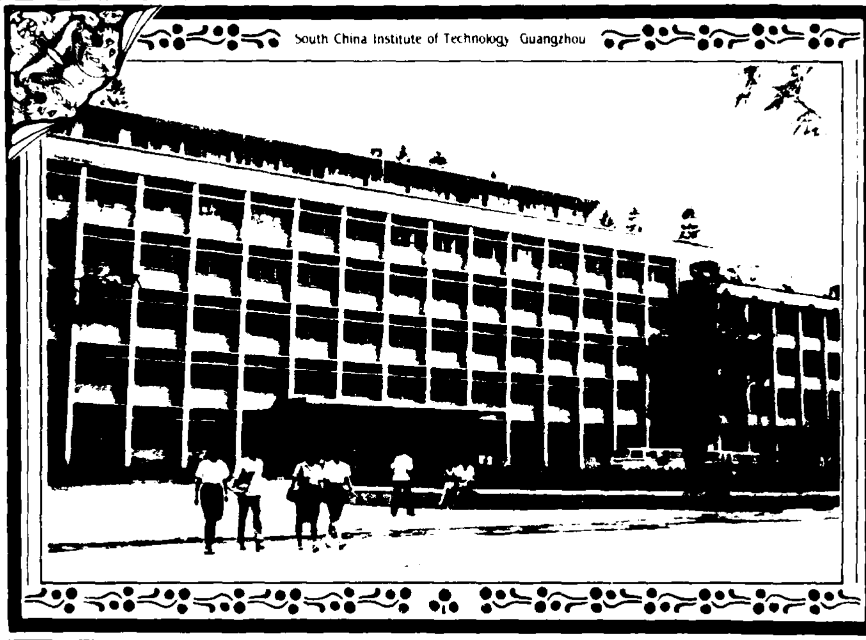
South China Institute of Technology (SCIT). The SCIT, located in the Gaungzhou (Canton) area, offers specialized programs in engineering and physical sciences. It is one of China's national institutions under the Ministry of Education.

There are 18 departments offering 43 specialities. In addition, SCIT has three research institutes, an architectural design institute, and 12 independent research units.

The institute runs four factories: machine-building factory, radio factory, chemical machinery factory, and rubber factory. These factories, with a staff of 420 persons (including 26 engineers), are equipped with 1,600 pieces of equipment. The equipment includes such heavy-duty precisionmachines as universal surface grinders, milling machines, external grinders, and jig borers for use in teaching and in scientific research, and for the trial manufacture of new products.

The SCIT owns a printing house and operates a hospital, retail shop, primary school, and kindergarten. These are designed to serve the welfare of the teaching, administrative, and support staffs of SCIT.

All programs of study at SCIT grant bachelor of science degrees. The following programs of study are authorized to grant doctoral degrees: machine-building, history and theory of architecture, communica



- ORGANIZED: 1980 BY CHINESE MECHANICAL ENGINEERING SOCIETY
- AGE OF STUDENTS: 27 TO 50 YEARS
- TUITION: PAID BY COMPANY, OR COMPANY AND STUDENT SHARE COST
- NUMBER OF STUDENTS WHO HAVE COMPLETED 10 COURSES: 3000
- COMPANIES PROVIDE TIME FOR STUDY: PERHAPS, ONE DAY/WEEK

SUBJECTS STUDIED INCLUDE, BUT NOT LIMITED TO THE FOLLOWING:

MECHANICAL DESIGN	MANUFACTURING
ELECTRO-MECHANICAL TECHNOLOGY	THERMAL TREATMENT
RELIABILITY	MANAGEMENT ENGINEERING
ECONOMICS	MODERN MATERIALS
SYSTEM ENGINEERING	TESTING TECHNIQUES
LOGISTICS ENGINEERING AND CONTROL	INTERNATIONAL STANDARDS
COMPUTERS	LAW

- EXAMINATIONS: TWICE A YEAR
- COLLEGE NOT RECOGNIZED BY THE "STATE"

Figure 2
College of Continuing Education

tions and electronic systems, sugar refining, chemical fluid mechanics, and heat transfer. The Institute has more than 30 000 graduates.

The SCIT library has reading rooms and teacher's reference rooms capable of accommodating 800 readers at a time. It has more than 850,000 books and 3,300 periodicals written in Chinese and foreign languages.

In recent years, SCIT has strengthened academic relations with institutions and educational organizations overseas, as well as with Hong Kong and Macao. It has invited well-known scholars and specialists from the United States, Great Britain, Canada, the Federal Republic of Germany, Japan, Denmark, and the Hong Kong-Macao area to teach and/or present lectures, and participate in international conferences. Faculty members have gone to places like the United States, Great Britain, Canada, the Federal Republic of Germany, Japan, Austria, Sweden, the Netherlands, Denmark, Norway, and France to study or perform short-term research projects. This program has helped to intensify SCITS (and China's) cultural relations with people in other parts of the world.

National Defense University of the People's Liberation Army. Although I did not have an opportunity to visit it, I learned that China has a defense university that is an amalgamation of three military academies, each of which has a specialty: military affairs, logistics, and politics. The university reports to the Central Military Commission of the CCP Central Committee.

The university offers a comprehensive college education for in-service army, navy, and air force officers, above the deputy division level, who are selected by their organizations and able to pass an entrance examination. Officers attend classes together like the service students at the DSMC. To graduate, they must demonstrate a good understanding of military affairs, logistics, and politics, as well as of economics and diplomacy. According to Zhang Zhen, president of the university, the university stresses CCP structure and political activities. This is the fundamental difference between the Chinese university and national defense universities in other countries.

Since its inception, the National Defense University has developed more than 100 courses. These include Soviet and U.S. military strategies, international strategy, space race, organizating and directing combined actions to resist foreign agression, contemporary world politics-economic environment, and computerized exercises in simulated warfare. The university invites distingushed guests, specialists, and scholars, to address students. Guest lecturers represent more than 20 foreign countries.

The university has more than 500 teachers and researchers. Criterion for the selection of military and civilian faculty members, young or middle-aged, is that they be good teachers and/or researchers.

The library contains 1.2 million books.

Colleges of Continuing Engineering Education. Details pertaining to the college are outlined in Figure 2.

工程師研究

ENGINEERING RESEARCH

Delegation from the United States Meeting with Faculty College of Continuing Education

The role of engineering in the modernization of China is crucial. China's goal to modernize its science and technology, agriculture, industry, and national defense by the end of the century can not be met without engineering support. Although engineering is expanding rapidly in China, the demands imposed by an increasingly technological society are growing.

During the past 38 years, development of engineering in China has been impressive even though political and ideological disruptions caused setbacks. During the first 17 years after the founding of the People's Republic (1949-1966), there were impressive engineering achievements. During the Cultural Revolution and its aftermath (1966-1976), stagnation settled in. Since 1976, engineering in China has been spurred on by the plan for Four Modernizations, which I addressed previously.

Some of the significant engineering research in China is carried out in the research institutes operated under joint jurisdiction of the industrial ministries and the provincial or municipal governments. However, research and development activities in medium and large-size factories have helped to solve industrial problems and improve production processes and associated machinery. Some of the large industrial enterprises in China have research facilities; others operate jointly with one of the industrial ministries. Most military-oriented engineering research is classified and will not be discussed here.

In China, there are seven Ministries of Machine Building; namely, the First Machine Building Ministry, nuclear weapons, aircraft, electronic equipment, conventional armaments, ships, and missiles and aerospace systems. Although some ministries are totally military oriented, most provide machines and equipment for civilian and military purposes.

Many ministries are involved in technology in addition to their primary functions. These ministries include light industry, metallurgical industry, chemical industry, petroleum industry, coal industry, textile industry, electric power, telecommunications, railways, transportation, and water conservancy. Each has about 10-20 research institutes under its jurisdiction. Some have joint jurisdictions with large factories or local governments.

GENERAL ZHANG ZHEN

The First Machine Building Ministry, for example, has more than 15 general research institutes under its jurisdiction. These research institutes are involved in research on general machinery; heavy machinery; machine tools; abrasives and grinding tools; bearings, castings, and forgings for argicultural machinery; construction machinery, cranes, and transport; hydraulic pressure instruments and meter technology; material, motor vehicle, scientific and technical information; and several academic research institutes.

Although engineering research is emphasized in Chinese universities/colleges, the research appears to be on a smaller scale than in the United States. During the Cultural Revolution, as might be expected, university research was drastically curtailed. It has taken many years to rebuild the equipment and facilities destroyed at that time. Today, many faculty members interested in research find it worthwhile to go abroad to countries like the United States for advanced study. However, a few bright spots exist in engineering research in China today because of strong, persistent efforts of some faculty members.

工ㄍㄨㄥ業ㄧㄝ

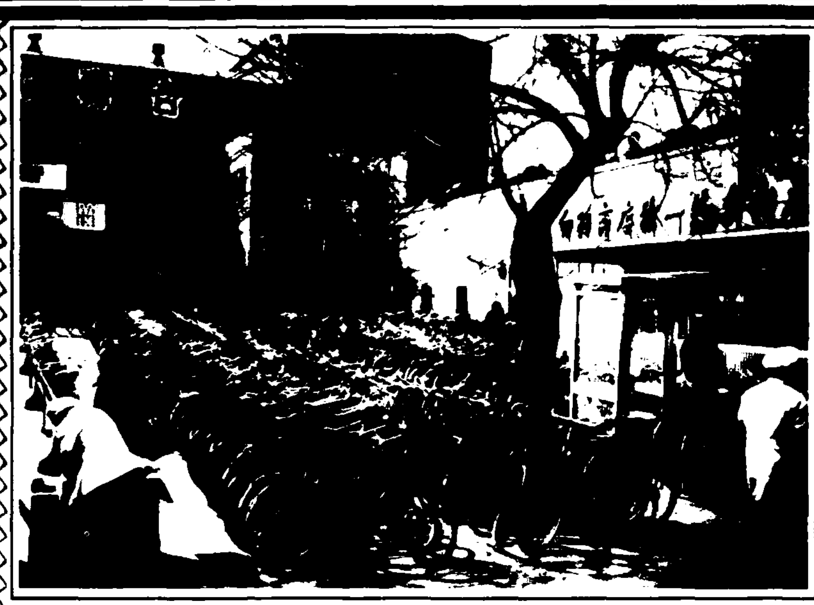
INDUSTRY

Industry is under state ownership and direction, and some of its technological capabilities appear to be behind those of the advanced industrial nations. However, China is showing a strong interest in becoming an industrial leader.

Chinese technology was on display at the Sixty-First Export Commodities Fair in Guangzhou in April 1987. At the fair, I learned that most of the large industries are located in urban areas of the coastal provinces; e.g., Shenyang, Changchun, and Anshan in the northeast, and Nanjing and Guangzhou in the south. They are also located in the independent municipalities of Beijing, Shanghai, and Tianjin. Although the central government has made a concerted effort to relocate some large industries inland, only one-third are located there today. The main inland industrial centers are Xian, Wuhan, Lanzhou, and Chongqing.

Large industrial complexes have been established for such basic industries as machine-building, automotive, electronic component, metallurgical, and petrochemical. Many of these industries began with the massive transfer of Soviet technology and equipment to China in the 1950s. Of course, these industries have been modified and expanded by the Chinese since then. Recently, the basic equipment required to establish large industrial plants have been imported from Japan and Western Europe. However, the Chinese are showing a real interest in American know-how and importing equipment from the United States. Industrialists readily admit that advanced foreign know-how is needed if China is to achieve a much greater production capabiity in a relatively short time.

Four thousand enterprises — 51 percent of China's total enterprises — have adopted a contractual responsibility system. Lu Dong, minister in charge of the State Economic Commission, has stated that under the system managers take responsibility for marketing, production, product quality, and workers' benefits. They are



Workers' Bicycles Parked in Front of Company, Shenyang. There Are 71 Million Bicycles in China.

Below: *Chinese Woodcut* *Courtesy Rita Aero* **Things Chinese.**

rewarded when they meet quotas and penalized when they don't.

"The spread of the system nationwide indicates that China's enterprise reform has entered a new stage with the focus on improving the management mechanism," Lu said. The system separates the ownership of enterprises from managerial authority. This enables enterprises to assume explicit economic responsibility, and to enjoy full managerial authority and economic benefits, while the State retains ownership of the enterprise. Lu indicated that the system also combines reform with enterprise development. It gives impetus to tapping the full potential of enterprises and encourages increases in production and cost-saving.

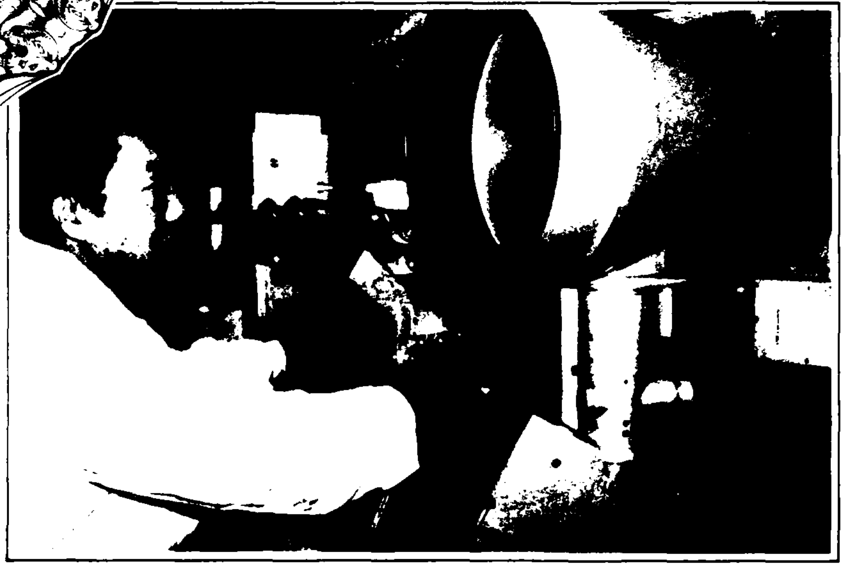
Let's examine briefly what is happening in four basic industries namely: iron and steel, machine tool, automotive and shipbuilding.

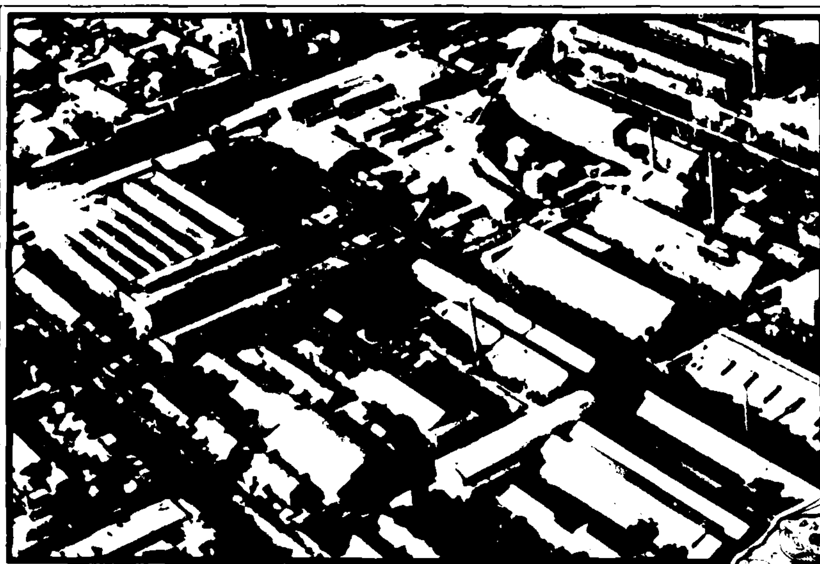
Iron and Steel Industry

The iron and steel industry provides basic construction materials for all industries; therefore, it is fundamental to technological development. Although China suffered severe setbacks when the Soviets withdrew technical aid and the Cultural Revolution took place, production of crude steel has increased dramatically since 1949. Unfortunately, the increased steel output has not met the growing demand by industry. China is a significant importer of iron and steel products from the industrialized nations.

The potential for China to grow substantially in the iron and steel industry exists because it has a large supply of iron and coal. China ranks third in coal reserves, behind the United States and the Soviet Union. Supplies of other ingredients, such as magnanese and limestone, are adequate in China.

Engineer Making Observation at the Metalscope





Courtesy of Shenyang No. 1 Machine Tool Works

Aerial View of Shenyang No. 1 Machine Tool Works

Machine Tool Industry

The machine tool industry supplies most capital equipment for components used in machine-building. China is capable of meeting the demand for general purpose machine tools, but it has to import some precision and specialized machine tools. China has been able to export some ot its basic machine tools to Western nations because the prices it charges are competitive. Among machine tools marketed are gear-grinders, gear-shaping machines, lathes, and optical profile grinders.

Major production centers for metal-cutting and metal-forming tools are located in the east, north, and northeast — Beijing, Shanghai, Shenyang, and Haerbin. Typical of the large machine tool factories is the Shenyang No. 1 Machine Tool Works, which I visited.

The Shenyang Works is the largest comprehensive lathe manufacturer in China. Founded in 1935, it manufactures 10 types and more than 100 models of lathes including universal lathes, multi-spindle, semi-automatic lathes; CNC lathes; high-speed precision leadscrew lathes; high-speed precision lathes; pipe lathes; crankshaft lathes; cam-profile lathes; piston lathes; piston-ring lathes; and digital display lathes. The annual output is about 6,000 units.

The Shenyang Works employs 8,500 people including 36 senior engineers, 240 engineers and 724 technicians; the plant operates on two 8-hour shifts a day, 6 days a week, 52 weeks a year.

The company is recognized for producing quality products and providing good service to customers at home and in 40 foreign countries. Ten percent of the lathes are exported. More than 85 perent of the products have won state "Gold Medals" and "Silver Medals."

The technological level of China's machine tool industry lags behind the advanced industrial nations, but it is making a concerted effort to improve its position.

Motor Vehicle Industry

In China, a car is a luxury. Someone said, "The industry is in its cradle." Industrialized countries have an average of 200-550 cars for every 1,000 people. In China there is only 0.27 of a car for 1,000 people. This places China behind 139 countries in the world.

According to Wang Weimin, a Chinese official in charge of planning at the China National Automobile Industry Association, "China has less than 500,000 cars, of which 230,000 are jeeps." Most of the cars are imported because China has the capacity to produce only 20,000 cars annually. It is estimated that China will have 4 million cars, or about 3.3 cars for every 1,000 people by the end of the century, the same level as in Japan in the late 1950s. To come into its own, China's automobile industry must depend mainly on its own abilities, supplemented by advanced foreign technology. A forecast of the number of motor vehicles that will be in use and in demand in 1990 and 2000, prepared by the State Economic Commission in Beijing in the summer of 1987, is shown in Figure 3.

	YEAR	CARS	VANS	COACHES	TRUCKS	TOTAL
VEHICLES IN USE (IN 10,000's)	1990	70-80	25-35	35	370-400	500-550
	2000	300-400	150-200	80	770-820	1,300-1,520
VEHICLES IN DEMAND (IN 10,000's)	1990	9-13	5-9	6	47-56	67-84
	2000	60-73	29-39	10	87-90	186-212

TECHNICAL AND ECONOMIC RESEARCH INSTITUTE, STATE ECONOMIC COMMISSION, BEIJING 1987

Figure 3
Forecast of Motor Vehicles 1990-2000


Courtesy of China Pictorial

Evolved From An Auto Repair Shop Built in 1934. The Jinan General Motors Plant Is One of China's Heavy Duty Truck Manufacturers.

During the Cultural Revolution, provinces and municipalities throughout China began manufacturing motor vehicles for argicultural and transportation purposes. Today, more than 30 provinces, autonomous regions, and municipalities produce motor vehicles. Most plants are small and use low-level technology. The output is small and productivity is low. The large motor vehicle plants, which are designated lead factories, coordinate efforts of smaller plants and provide them with necessary guidance, technology, and training. Because increased production demands better planning and higher efficiency, specialized component and subassembly plants, such as those producing engines, chasses, and tires, have been started to supply the large assembly plants.

In 1987, trucks constituted approximately 70 percent of the total output the Chinese autmotive industry. The other 30 percent consisted of jeeps, sedans, and buses — not including small three-wheel motor vehicles, which are popular for transporting cargo in rural areas. General-purpose trucks are used for a wide range of transportation services, and the limited number of special trucks produced are used for transporting ore, lumber, construction materials, and petroleum.

The Changchun No. 1 Motor Vehicle Plant is the largest automotive plant in China. This plant accounts for about half of China's output. There are about 30,000 people employed at this plant — 20,000 in production and 10,000 in the auxiliary functions. The Changchun Plant plays a significant role as a center of technical training in the Chinese automotive industry.

When the first China-made, four-ton Liberation trucks rolled off the line at the Changchun plant in 1956, the public interest in motor vehicles was raised. In Shanghai, Nanjing, Jinan, and Beijing, a variety of models were for sale. They included the Yellow River and Leap Forward trucks. Trucks and remodeled buses began to appear in cities in place of carts. Chinese-made trucks began to appear at construction and mining sites and at the wharves.

The first sedan — the "Dongfanghong" (East is Red) — was produced in 1958 at the Beijing Motor Vehicle Plant. Among the more common sedans produced in China today are the premium-class "Shanghai," manufatured in Shanghai, and the "Hong-Qi" (Red Flag) built in Changchun, and the Beijing jeep.

In September 1969, China built its second automobile plant at Shiyan in Hubei province. This was the first time the plant and the automobiles were designed by Chinese engineers. About the same time, automotive plants were built in Sichuan and Shaanxi to manufacture heavy-duty trucks. This action spurred a second wave of enthusiasm about the automobile in China, and automobile factories sprouted up throughout the country. Unfortunately, products of the small factories have, for the most part, been inferior.

After 1979, sweeping economic reform penetrated cities and countryside, and there was a heavy demand for automobiles in rural areas. Early in 1983, the Changchun Number 1 Motor Vehicle Plant (sometimes referred to as the First Automobile Plant) received more than 5,600 orders from rural buyers. To meet the needs of farmers in 1983, the Chinese Automobile Marketing Service Corporation placed 10,000 vehicles on the market in 200 countries. As might be expected, news of automobiles owned by individuals in China made headlines in the world press.

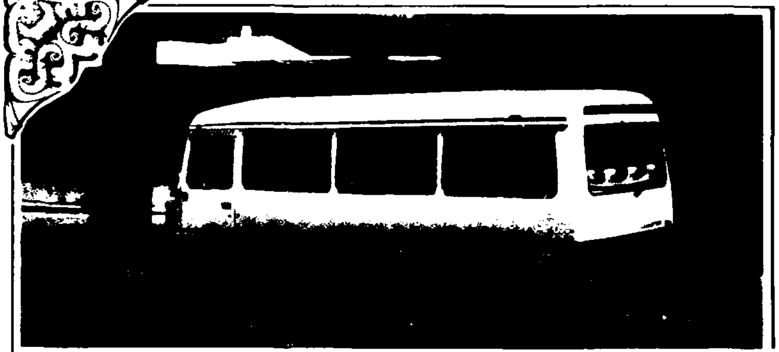
China's seventh Five-Year Plan has called for the automotive industry to become a basic industry. As a result, the Chinese Automobile Corporation, founded in 1982, has been actively pursuing links with foreign companies. Technicians have been sent abroad for automotive research and technical exchange, and for discussions geared to joint production of automotive products.

In late July 1987, it was announced that the Chrysler Corporation would help the Changchun plant produce four-cylinder engines for China sales. The agreement with Chrysler covers a technology purchase in which the Chinese company will receive 48 major pieces of machinery from Chrysler to build up to 300,000 four-cylinder engines annually for use in cars and trucks.

Automotive companies in China are updating models designed in the 1950s and diversifying their lines. Special attention is given to heavy-duty trucks and sedans. The Beijing jeep, a newcomer to the international auto market, has been praised by foreign customers.

The Chinese automotive industry is developing impressively, but it is backward relative to design of the models it produces and production methods it uses. China still imports a large number of trucks, and at the same time, is exporting about 10 percent of its own trucks to Third World countries. China's objective is to satisfy its domestic needs first and, then, to compete in the world market.

Chinese Built Bus



Courtesy of China Pictorial

The CA 141 A New Liberation Model During Road Test

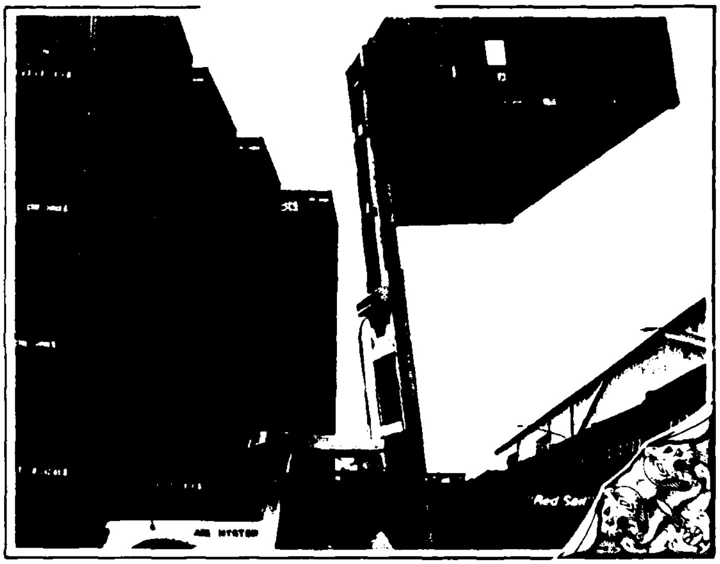
Shipbuilding Industry

At the China State Shipbuilding Corporation in Guangzhou, I learned some interesting facts about the shipbuilding business in China.

This shipyard — the biggest and most modern shipbuilding enterprise in the South China region — was build in 1954. Situated on the bank of the scenic Pearl River, it has two drydocks and three building berths. It employs more than 8,000 workers including 1,000 engineers and technicians. In 1980, it converted from military to commercial shipbuilding.

Watch Assembly Line in Loft at Guangzhou Shipyard

Floating Dock Guangzhou Shipyard



"Red Sail" Brand Steel Dry Cargo Containers. A Product of the Guangzhou Shipyard.

With modern technical and production facilities, along with managerial experience, the Guangzhou Shipyard has built 870 ships and repaired more than 780 ships for Chinese owners and others aboard. Supported by American engineers, the shipyard has been able to establish high technological standards and quality products.

Besides its building and repairing business, this shipyard manufacturers 20-feet-long steel, dry-cargo containers using the Red Sail brand. This container manufacturing factory is the first one in China built in cooperation with Civet Investment Co. Ltd. (of Hong Kong) and Container Transport International, Inc. (CTI). In this factory, there are 10 modern production lines and several highly efficient mechanical installations. The factory produces 10,000 Red Sail containers a year, refrigerated and non-refrigerated. Because of the high quality of its products, this factory has earned the state's "Silver Medal."

The Guangzhou shipyard provides services for other industries. Among the services it offers are manufacture of heavy cranes, pneumatic tools, and large and small machine parts; castings; wool-fabric hand-woven items, such as sweaters; and assembly of watches.

Now, let's consider the status of the Chinese defense program and the viewpoint of the Chinese leaders on world peace.

防備國家

DEFENSE

Among Deng Xiaoping's Four Modernizations, defense is always listed last. Apparently, Deng recognizes the dangers of a militarized society, but at the same time he knows the need for an alert and effective military organization. Thus, he has diminished the role of the military in society while forging a modern, but leaner, military machine. Recently, he reduced the number of military personnel from 4 million to 3 million, believing external threats are low enough to be managed through diplomacy. The reduction took longer than expected because of the resistance of officers cherishing influences and privileges.

China is divided into 11 military regions, which are subdivided in 29 military districts. Regions are subordinate to the People's Liberation Army (PLA) general staff. Senior military officers participate in leadership councils. The Chinese Communist Party (CCP) and the State Military Affairs Commission exercise political control of military forces; however, the role of the Ministry of National Defense is largely administrative. Military officers make up about one-third of the members of the Communist Party's Central Committee.

The percentage of the State budget devoted to military expenditures has dropped. Deng and allies have reduced military representation in the Politburo and the Central Committee, although defense officials still maintain that China is facing threats to its national security.

The PLA land-based force is composed of about 3 million military personnel and a "back-up" militia (citizen's army) of about 5 million. The naval force (about 300,000) is principally involved with manning coastal patrol-craft, submarines, and destroyers. The air force, which is the world's largest in terms of personnel (about 400,000), has many aging fighters and a few modern aicraft. The inventory contains a modest force of medium — and intermediate — range ballistic missiles, and limited-range intercontinental missiles. Large-scale operations of the military services are restricted because there is limited logistical support and few transport facilities are available.

The period of service for each military organization follows: army, 3 years; air force, 4 years; navy, 5 years.

Most foreign military experts believe the world's largest fighting force is at least 20 years behind the leading military powers of the world in terms of weapons technology. Morale is low and too many officers receive special privileges.

Modernization of China's defense systems is going to be based on the principal of self-reliance, indigenous production, and the receipt of selected imports from the West.

Because the cost of defense is high, a decision has been made by the Chinese government to have tourists help defray

PLA OFFICER

defense costs. By paying a fee, tourists will be able to fire bursts from anti-aircraft guns, submachine guns, and pistols at military installations. Tourists will be encouraged to purchase products and services including lotus-petal cream, jade wine cups, bicycles, motorcycles, washing machines, and optical instruments. The types of products sold to civilians have increased from 64 to more than 700 since 1980.

In August 1987, the Chinese army celebrated its 60th anniversary when the Army was portrayed as a modern force in the process of opening up to the outside world. The PLA, which formerly valued secrecy and viewed foreigners with mistrust, announced it is planning to send promising military officers to foreign military academies to study.

結論

CONCLUSION

The future of engineering in China — research, development, and education — depends strongly on the idealogical and political course it takes in coming years. History reveals that China's development since the founding of the People's Republic has been vacillating and unpredictable. Perhaps the deep commitment of the government to the Four Modernizations, along with the support of the Chinese people to this commitment, will bring about the rapid technological and economic development needed and desired by its citizens.

There is evidence that business opportunities for Americans exist in China, especially licensing and joint-venture agreements. However, it appears to me that a shortage of good management, lack of production-mindedness, and questionable quality control will make it difficult for many American companies to operate profitably in China today. There are some exceptions, and the new Chrysler agreement may be one.

Some American companies are developing good relationships with the Chinese. Our people who do business with the Chinese should be sincere, honest, and highly qualified in their fields. If they are, good relationships will be fostered. Needed changes in business and manufacturing in China may not take place as quickly as our people might like to see them occur, but I am hopeful that the changes will be worthwhile and beneficial for all concerned when they do occur.

Much speculation exists about the role of the Pacific Rim nations in the world's future economy. I am referring to China, Japan, North Korea, South Korea, Hong Kong, Taiwan, Southeast Asia, Australia, and the United States. Although differing in degree, the growth rate of the region is outpacing that of the North Atlantic region by almost 1.5 percent.

China, of course, is the great unknown among the Pacific Rim nations, but its potential is tremendous. Americans who have been studying China's recent financial restructuring generally agree that China will become a dominant force in the Pacific Rim in the next century. In March 1987, one Chinese leader told our Secretary of State, George P. Shultz, during his visit to the People's Republic, that modernization would continue "without either cultural Westernization or a return to repression." Vice Premier Li Peng, 58, a technocrat, said, "We will continue to introduce our students to advanced sciences, technologies, managerial experiences, and

LI PENG

culture of foreign countries." Shultz said he had no reason to question the sincerity of either statement.

It seems clear that China should continue to pursue widening its opening to the outside world and accomplish needed reforms in its economy. At the same time, it must overcome such difficulties as demands that surpass ability to supply, rising prices, budget deficits, and inefficient production of goods. The challenges China faces are formidable, but they can be met and overcome.

Erratum: The portrait of Zhou Enlai in Part I was incorrectly labelled Chang Kai Chek

SCHEDULES

PRODUCTION MANAGEMENT

Integrating Cost Performance With Line of Balance

Jerry Reeves
Joseph Maddock

The traditional line of balance has proved to be an effective tool for tracking and managing production schedules. Until recently, it has lacked ability to provide the same focus on costs, thus requiring other systems to provide this information. Yet, line of balance inherently incorporates most elements required to provide management with visibility into cost and schedule performance. Our report explains an enhancement to the line of balance concept we developed to integrate the traditional line of balance with elements of C/SCSC, resulting in a single work measurement system. This system is being implemented for a classified program at Simmonds Precision Products Inc., subsidiary of Hercules Incorporated. The IBM-PC compatible software was developed in a joint venture between Simmonds and TRW Electronics Products Division which automates calculations and provides computer generated graphics.

Traditional Line Of Balance Concept

To fully understand the enhanced concept and additional benefits it provides management, we will guide a review of the traditional concept.[1]

The traditional line of balance (LOB) technique involves four phases or elements which is summarized below (see Figure 1).

Objective: This is the cumulative delivery schedule requirement for an end-item along with the status of actual deliveries at the time of the study. These are plotted on the same chart to indicate the cumulative planned versus actual end-item deliveries.

Production Plan: This is the sequence and setback times for the planned production process.

Progress: This is a bar chart which presents the quantities of material, parts and subassemblies at control points tied to the production plan via milestones.

Striking Line of Balance: This provides the basis for comparing the progress to date with the objective. The line depicts the quantity of end-item sets for each milestone which must be available to support the planned delivery schedule. With this line, the manager quickly can determine the status of work in process, identify problem areas which may impact schedule performance, and focus attention on the timely resolution of the problems to recover and maintain the schedule objective.

Obvious benefits of the LOB have been attested by Department of Defense production programs incorporating its use. While implementing it on the U.S. Air Force B-1B Program at Simmonds Precision, we noted one drawback: the amount of administrative labor required to manually update the graphics. To reduce this burden, we contracted with TRW Electronic Products to develop an IBM-PC compatible application software program which automates the system and provides computer generated color graphics. The result proved to be more cost-effective to maintain, and has been successfully applied at Simmonds and other aerospace firms.

Enhanced Line of Balance

While the line of balance provided important information concerning schedule status of work-in-progress, the equally important cost status had to be obtained elsewhere. While discussing this deficiency, we decided to develop a unique enhancement to the LOB software package by integrating budgeted cost of work scheduled (BCWS) with the system to obtain corresponding measurements of cost performance within a common database. The following presents an overview of the concept, its basic elements, and the graphic outputs of the integrated software package.

Budgeted Cost of Work Scheduled (BCWS): As shown in Figure 2, the Enhanced Line of Balance (ELOB) concept builds upon the traditional LOB elements and integrates budgets (BCWS) for each milestone by unit, task, skill, cost center, and cost account. The ELOB software program performs all learning-curve calculations and assigns budgets for each unit-number and milestone.

The program prompts the user for the following budgeted cost of work schedule input data:

—Top assembly number (end-item)

—Specific operation from the production plan

—Cost account code

—Cost center code

—Factory rate for the skill code (or material dollars per kit)

—Labor skill code, material or other direct cost codes

—Charge (job) numbers for the operation (may be several assigned for an operation like fabrication, inspection)

—Number of units to be delivered

■ *Lieutenant Colonel Maddock, USAF Retired, is a Director and Program Manager for Simmonds Precision Products Inc., Instrument Systems Division. Major Reeves, USAF Retired, a graduate of PMC 75-1, is an independent consultant for program management.*

Figure 1. Traditional Line-of-Balance Outputs

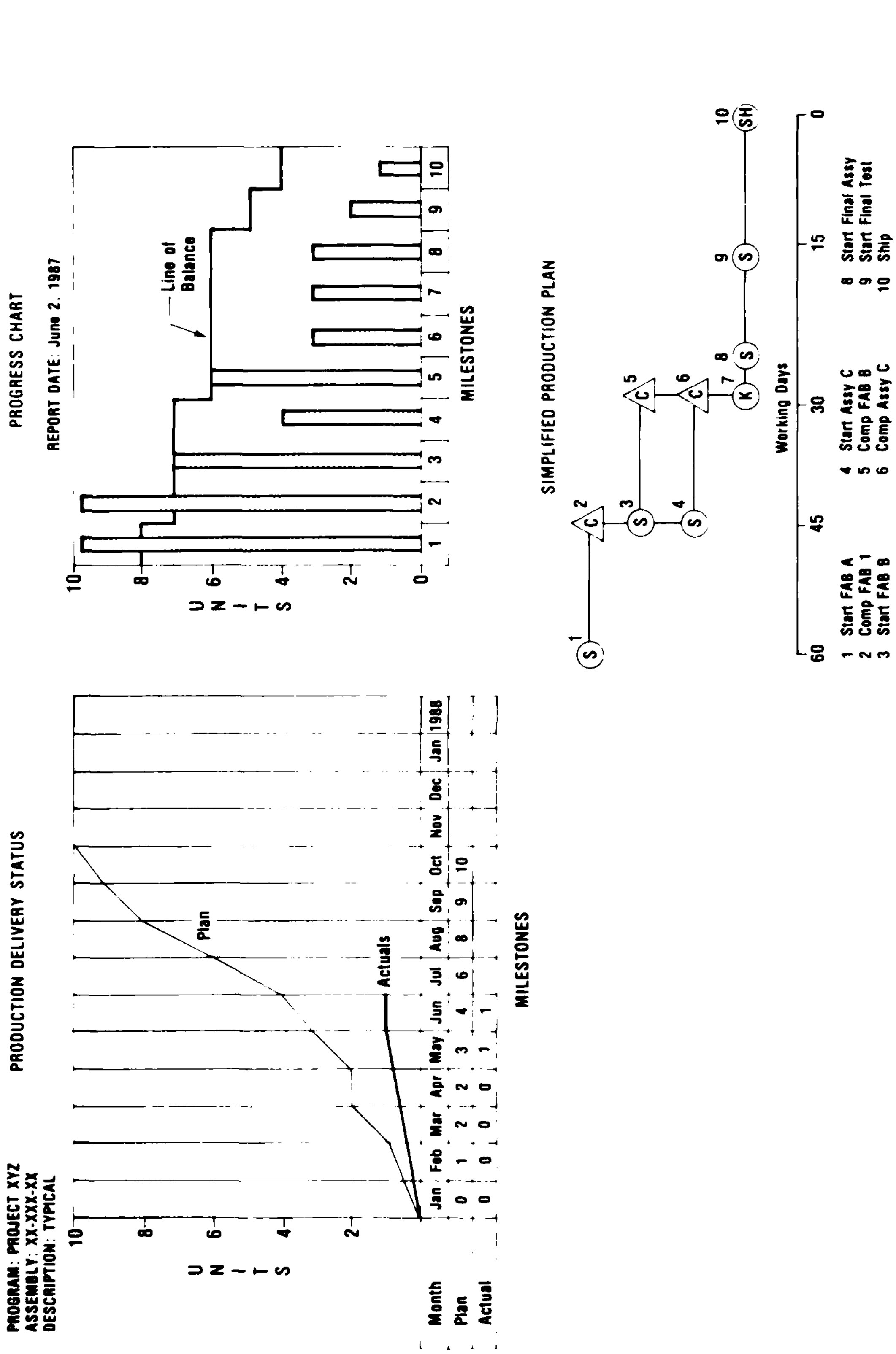
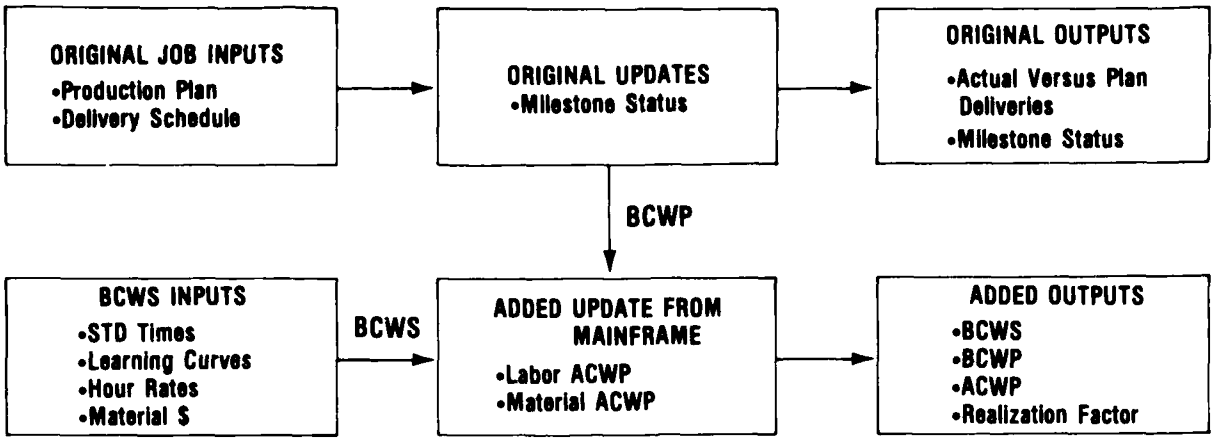


Figure 2. Enhanced Line-of-Balance Concept



INTEGRATES BCWS COST ELEMENTS INTO ORIGINAL LINE-OF-BALANCE SYSTEM AND COLLECTS COST PERFORMANCE (BCWP, ACWP) BY TASK, SKILL AND COST ACCOUNT

—Percent spread between start and completion of an operation (required for collecting earned value)

—Standard unit, for which the standard time is to be achieved

—Learning curve percent for specified task.

Material budgeted cost of work scheduled can be included as a skill code entry with the dollars assigned at kitting milestones (point of usage). Other direct costs can be assigned for any operation as a separate skill-code entry. Thus, all basic elements of costs can be incorporated and tracked with the system.

Once inputs for each operation leg of the production plan are complete, the ELOB software program develops a learning-curve-adjusted BCWS for each unit by operation, skill, etc., and spreads the budget (hours and dollars) as desired between the start and completion milestones for that operation. The aggregate of budgets for all operations of the end-item establishes the performance baseline and is permanently stored in the computer with access controlled by password. As milestones are statused and a study is performed, the BCWS is displayed on the cost progress chart as of the date of the study (Figure 3). This provides a reference for measuring variances between value of work earned (budgeted cost of work performed) and the BCWS at the time of the study.

Budgeted Cost of Work Performed (BCWP): As each milestone is statused for the original LOB portion of the system, the budget associated with work performed is spiked out and displayed. This represents the earned value of work performed as of the report date. When compared with the actual cost of work performed, cost variances are identified in hours and in dollars. When compared with BCWS, schedule variances are determined by hours and dollars.

Budget at Completion (BAC): The total budget for each milestone is provided as a reference line for measuring the progress of BCWP toward its completion. When the BCWP equals BAC, the milestone is complete for all units.

Other direct costs can be assigned for any operation as a separate skill-code entry. Thus, all basic elements of costs can be incorporated and tracked with the system.

Actual Cost of Work Performed (ACWP): For each report date, the actual costs are downloaded from the accounting database to the PC housing the ELOB software. These costs are then displayed along with other elements in both hours and dollars to complete the graphic display of cost performance.

Cost Performance Reports

The enhanced line of balance provides the following graphic and tabulated reports in addition to the traditional LOB outputs: (Figures 3 and 4).

Cost/Schedule Performance: Provides cumulative cost performance status (BCWS, BCWP, and ACWP) to date for end-item. It corresponds to the objective for the traditional line of balance.

Cost/Schedule Progress Chart: A bar chart providing a cumulative cost performance status for each milestone associated with the production plan.

Tabulated Work Package Summary: Provides detailed cost and schedule performance status at the work package levels.

Tabulated Functional Summary: Provides detailed cost and schedule performance status at the functional levels.

Figure 3. Enhancements to the Line-of-Balance—Total Cost (Similar Graphs for Labor Hours)

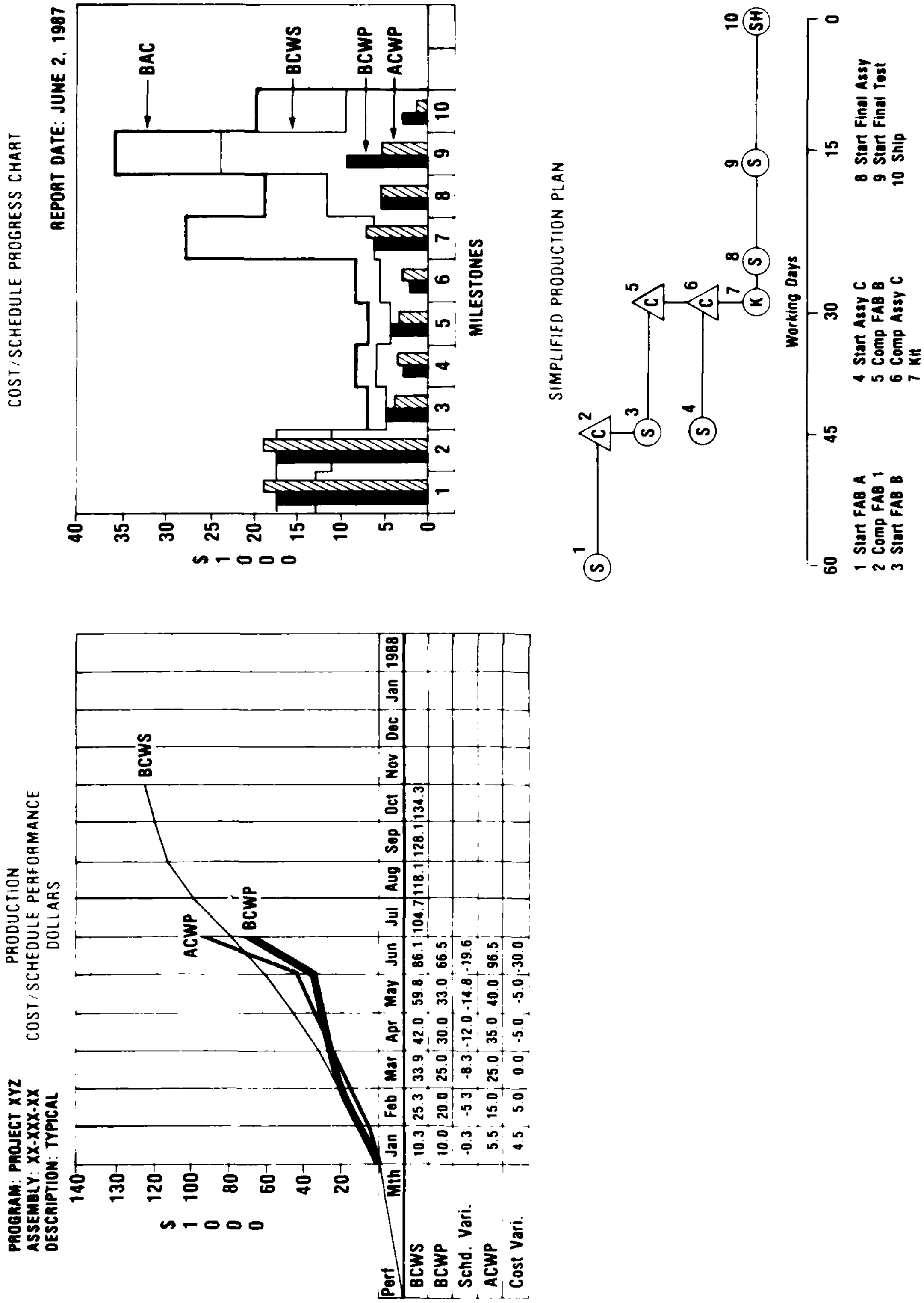
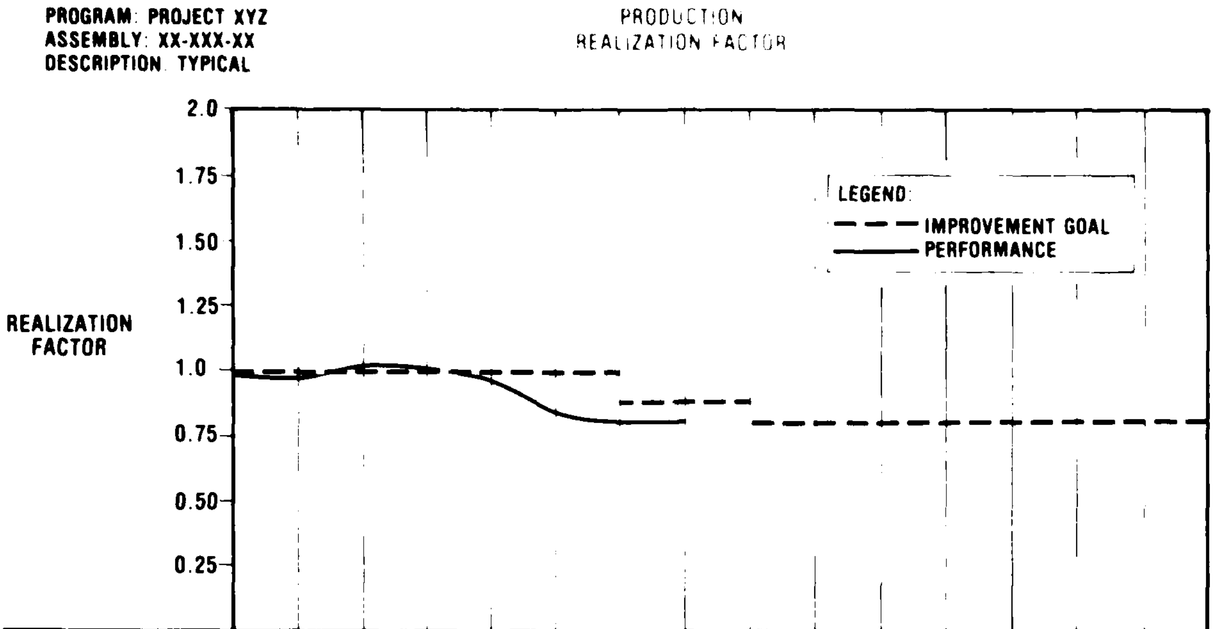


Figure 4. Sample Realization Factor at End-Item Level $\frac{ACWP}{BCWP}$



Perf / Mth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
ACWP CUM	190	205	225	290	290	305	310								
BCWP CUM	195	200	220	300	340	370	380								
RATIO CUM	0.97	1.03	1.02	0.97	0.85	0.84	082								

Benefits from ELOB

Additional significant benefits the ELOB brings to production program management can be summarized as follows:

—Provides for budgeting, proposal estimating, production planning, and material and touch labor performance evaluation using standard times adjusted for learning.

—Measures value and schedule of work-in-progress at any point in time.

—Measures planned versus actual cost and schedule performance, and quantifies cost and schedule variances from plan in tabulated formats.

—Enhances early identification of cost and schedule problems.

—Identifies man loading requirements over time by skill.

—Supports C/SCSC tracking, control and reporting requirements.

—Provides historic and project costs for subassemblies thereby improving visibility of logistic support costs.

—Supports MIL-STD-1567A performance measurement requirements by determining standard accuracies (adjusted with learning) through measurement of actual performance and comparing with the plan. Thresholds can be established which would trigger requirements for analysis and corrective actions. Simmonds Precision is proposing the use of ELOB as an alternate work measurement system satisfying the intent of MIL-STD-1567A by measuring the realization factor $\frac{ACWP}{BCWP}$ standards, and by reducing equipment costs through establishing and measuring improvement goals for each end-item (Figure 4).

With the ELOB, schedule and cost performance status are available in a single-work measurement system.

Conclusion

With the ELOB, schedule and cost performance status are available in a single work-measurement system. The IBM-PC compatible application software program adds the benefits of automation and cost-effectiveness for maintenance, reporting, and updating the plans and budgets as changes occur. The outputs provide you, the user, with a complete picture of end-item cost and schedule performance status in a consistent and easy to understand format.■

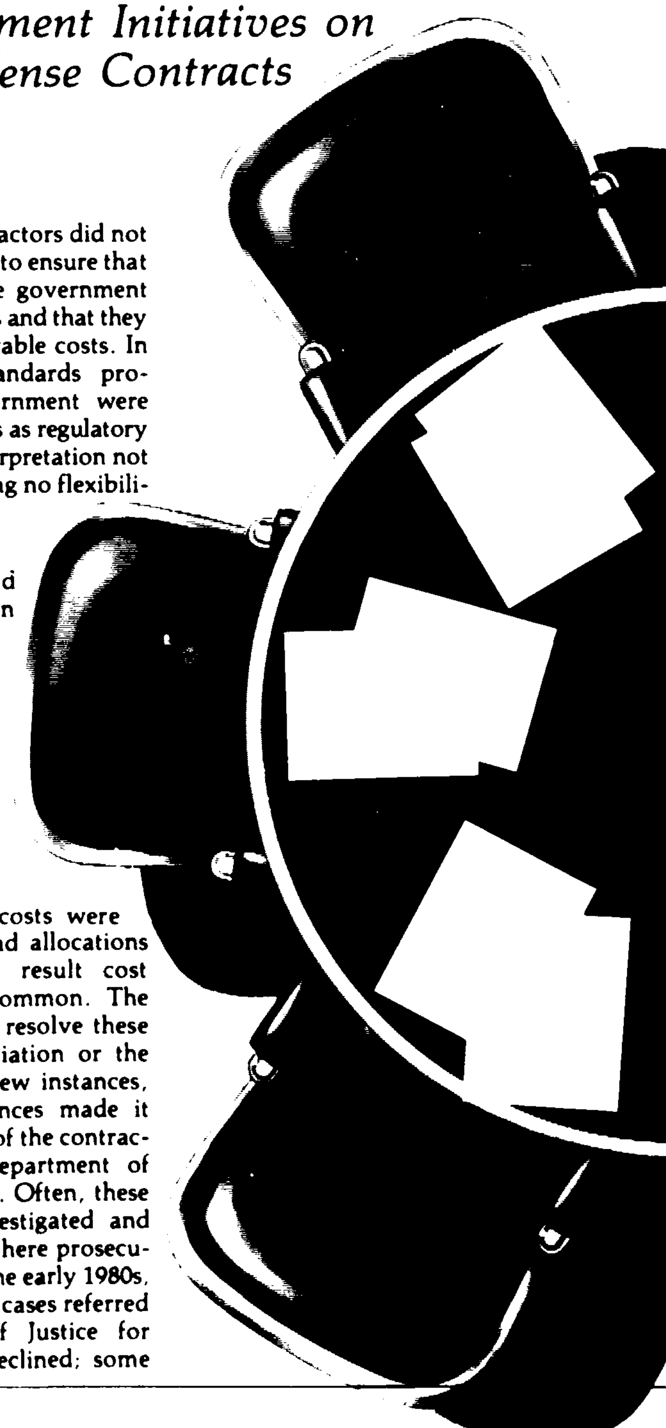
Endnote

Project Manager's Handbook, Vol. II, Reading 3-03, Procurement Associates, Inc., Covina, Calif.

PRT REPORT

CONTRACTOR SELF-GOVERNANCE

Government Initiatives on Defense Contracts



In the late 1930s, military contracting officers began using the cost of contract performance as a major factor in establishing a fair and reasonable price. During World War II, virtually all Department of Defense weaponry was acquired by means of such cost-based contracts, principally cost-plus-fixed fee and fixed-price redeterminable contracts. This great reliance on the cost of contract performance, which continues today, made it essential to set uniform rules and standards for determining the "costs" of contract performance.

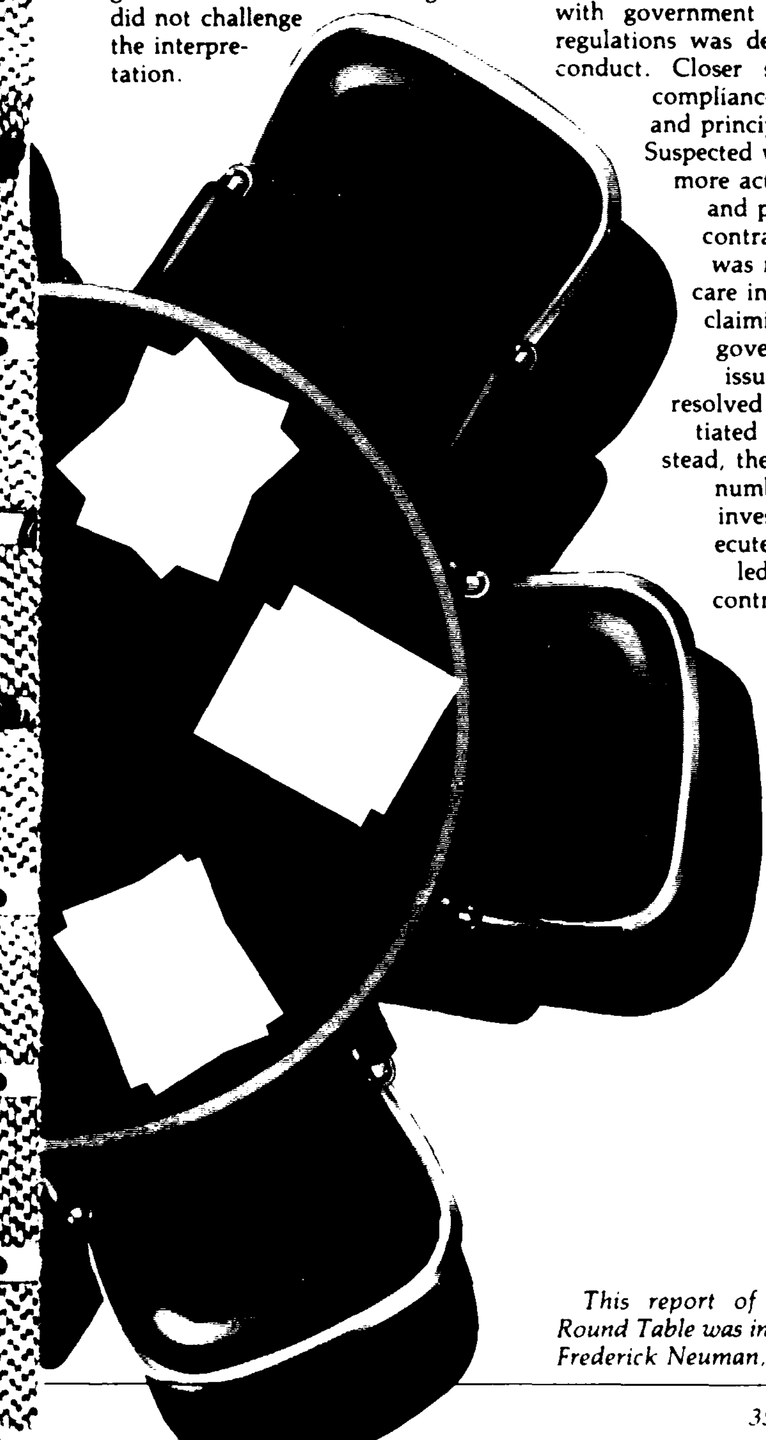
The initial standards were "cost principles." A simple set of principles was issued in the 1940s with Treasury Decision (TD) 5000. More elaborate cost principles were adopted in the 1950s and 1960s and, today, the Federal Acquisition Regulation (FAR) provides comprehensive criteria for recognizing costs that are allowable and those that are unallowable. In the 1970s, additional standards were provided in the form of Cost Accounting Standards (CAS), promulgated under PL 91-379. These standards provide formal guidance for measuring costs and assigning costs to final cost objectives, or allocating costs to contracts. In addition, these regulations require contractors to estimate, accumulate, and report costs incurred in the performance of government contracts in a uniform and consistent manner.

This system of rules and standards was imposed on a large number of contractors whose accounting practices were varied, with relatively little control or consistency. A gradual discipline was invoked, primarily as a result of government surveillance and issuance of regulations. The policies, procedures, and systems of internal controls instituted by some contractors during most of this period were usually directed toward the overall financial integrity of the company; that is, the company was primarily concerned with preserving assets, minimizing liabilities, and earning a net profit for the owners. Less attention was given to the precise assignment or allocation of costs to projects or contracts. The internal audit function, where one existed, and the annual financial audit performed by some companies' independent CPAs, provided little surveillance of the cost distribution methodology employed within a company's projects and contracts.

Similarly, some contractors did not exercise stringent efforts to ensure that claims submitted to the government were totally free of errors and that they did not include unallowable costs. In general, rules and standards promulgated by the government were perceived by both parties as regulatory guidelines subject to interpretation not as precise rules permitting no flexibility or negotiations.

In this environment, government auditors and contracting officers often concluded that contractors had made errors or had erroneously interpreted the government regulations in their reporting of costs claims for cost reimbursement or for additional compensation. In such cases costs were disallowed and overhead allocations challenged, and as a result cost disputes were not uncommon. The general practice was to resolve these disputes through negotiation or the disputes process. In a few instances, questionable circumstances made it necessary to refer some of the contractors' claims to the Department of Justice for investigation. Often, these referrals were not investigated and even more rarely were there prosecutions. In was noted, in the early 1980s, that two-thirds of fraud cases referred to the Department of Justice for criminal action were declined; some cases were declined because that Department did not have adequate resources to pursue prosecution. Sometimes, there was insufficient evidence or lack of prosecution merit.

This attitude toward rules and standards governing proper costs to be charged the government had negative effects on the procurement process. Contractors were motivated to interpret the regulations in the most favorable light possible with the possibility of overcompensation if government auditors or negotiators did not challenge the interpretation.



This attitude of flexibility led to laxness in other contractor practices in some cases, such as employee timekeeping procedures and preparation of bids and proposals submitted to the government. Contractors often submitted claims for additional compensation with little or no recognition of the applicability of the rules and standards for determination of costs.

In the 1980s, the government attitude changed. Efforts were made to rewrite cost principles to state more definitive rules, and non-compliance with government interpretation of regulations was defined as criminal conduct. Closer scrutiny of non-compliance with regulations and principles was initiated. Suspected wrongdoings were more actively investigated and prosecuted. Where contractor management was not exercising due care in the charging and claiming of costs under government contracts, issues were no longer resolved solely on a negotiated financial basis. In stead, there was a growing number of cases being investigated and prosecuted which, in turn, led to an increase in contractor suspensions and debarments.

This report of the Procurement Round Table was initially prepared by Frederick Neuman, a board member.

This report concerns recent self-governance initiatives by government contractors and suggests criteria for assuring compliance with procurement laws and regulations.

Discussion

Today, government contractors are aware that a concerned and responsible government will aggressively enforce compliance.

Critieria for contractor compliance have been adopted by a significant segment of the defense industry and endorsed in principle by the Department of Defense and the Department of Justice. More than 30 defense contractors have agreed to a program requiring them to follow a written code of business ethics and obligating them to monitor compliance with procurement laws and to adopt procedures for voluntary disclosure to the government of indentified violations.

At about the same time, Deputy Secretary of Defense Willian H. Taft IV wrote to 87 major defense contractors urging them to adopt a policy of voluntarily disclosing actions adversely affecting their corporate contractual relationship with the Department of Defense. Such a policy, coupled with full cooperation and complete access to necessary records, would be regarded by the Department of Defense as a strong indication of contractor integrity and an important factor in any Department of Defense decisions. Mr. Taft further stated the Department of Defense would take the following actions under such a program:

— Identify the Department of Defense component responsible for decision-making on suspension/debarment considerations. The Department of Defense Inspector General would provide information on voluntary disclosure by the contractor. The contractor could provide current information of corrective measures already taken to ensure the government need not suspend or debar the company.

— The Department of Defense, with cooperation of the Department of Justice, would seek to expedite completion of any investigation or audit.

— The Department of Defense would advise the Department of Justice of the complete nature of the voluntary disclosure in the latter's consideration of any sanctions that it might wish to pursue.

The guidance of U.S. attorneys will take the form of a supplement to the U.S. Attorney's Manual. The Defense Procurement Fraud Unit will continue to be the contact point for reviewing all voluntary disclosure issues.

At least half a dozen voluntary disclosure cases have been received by the Department of Defense Inspector General since Mr. Taft's letter was issued. Major defense contractors appear to agree that an effective contract compliance program is vital to their continued performance of government work. Demonstration of a strong commitment to ethical conduct, and accountability to the public, is needed to re-establish confidence in the integrity of the defense acquisition process.

Some contractors have concluded that voluntary disclosure is an essential step in reducing the number of prosecutions and have established policies of full disclosure. Other companies are weighing legal implications of voluntary disclosure with regard to the principle of attorney/client privilege and implications where employees make disclosures to corporate counsel about matters in which they may be involved in some violations.

In its Final Report to the President (June 1986), the Packard Commission stated "major improvements in contractor self-governance are essential," (p.80) and concluded:

> The Commission believes that self-governance is the most promising mechanism to foster improved contract compliance. It follows that each contractor must individually initiate, develop, implement, and enforce those elements of corporate governance that are critical to contract compliance, including a proper code of conduct. The extent of each contractor's efforts in doing so will reflect the level of reputation for integrity it intends to set for itself. (p. 84)

Contractor Compliance Criteria

Contractors will be required to do much more than in the past to comply with contractual, regulatory, and statutory standards and to provide adequate supervision and instruction for employees. To accomplish this will necessitate that contractors put in place broad and effective systems of internal control. The effectiveness of such systems depends on many factors, including:

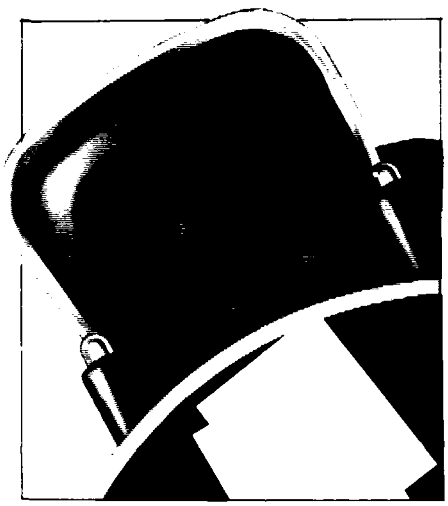
— Good organizational structure, providing for proper delegation of authority and differentiation of responsibilities;

— Clear policies and procedures, well adapted to business objectives and to specific tasks and functions;

— Training of, and communication with, employees at all performance levels;

— Ongoing arrangements to monitor compliance with and evaluate continuing efficacy of internal control.

In its final report to the President, the Packard Commission stated "major improvements in contractor self-governance are essential."



Additionally, contractors should adopt and implement a set of principles of business ethics and conduct that acknowledges and addressed their corporate responsibilities under federal procurement statutes and regulations.

A company code of business conduct should be issued as a formal document, clearly stating the company's policies and providing sanctions for violations. The implementation, in the form of procedures, should assign organizational responsibility for conducting examinations, hearings, etc.; also, for detecting violations, and methods for imposing sanctions. These formal documents should be disseminated to all personnel, including the newly employed.

There is a need for periodic acknowledgment by all personnel of their understanding of this code. The internal auditor would then periodically validate the above process, including evidence that the practices are in place and in compliance with written policies and procedures.

Government Criteria for Assessing Compliance

Notwithstanding all contractor efforts to ensure compliance with proper practices and procurement statutes and regulations, full or perfect compliance can never be achieved, except in the short-term. Therefore, the government should consider criteria for judging a contractor's compliance. The following criteria are suggested:

—Extent to which top management commitment to contract compliance is articulated and practiced;

—Efficacy of the organization's ongoing efforts as demonstrated by written policies that are current, complete and clear, procedures that are comprehensive and comprehensible at all need-to-know levels, policies and procedures that are in compliance with government requirements, an organization that produces an optimum degree of checks and balances, a trained cadre of professionals to monitor all of the above, and an ombudsman and/or hotline procedures to augment the internal audit function;

—Disclosed breaches are remedied promptly;

—Prompt examinations are made of all reported problem areas;

—Suspected violations are pursued speedily, comprehensively, and vigorously within company;

—Sanctions are taken against violators, appropriate to the irregularity;

—Financial restitution and appropriate disclosures are made to responsible government officials.

In such an environment, the company must make an effort in good faith to comply with government requirements. Although it is recognized that violators of laws or regulations generally cannot be given blanket immunity, it appears that government reaction should be along the following lines:

—An examination could be conducted of the actions taken by the contractor to evaluate whether actions are appropriate to the circumstances, financial restitution offered is sufficient, sanctions are sufficient, additional prosecution is appropriate, remedial actions are sufficient to minimize further similar exposures and safeguard government interests in future operations.

—Based on these evaluations, the government could conclude that the contractor has performed in an optimum manner to achieve contract compliance and:

—Suspension or debarment actions are not needed to preclude similar actions in the future;

—Further investigation by the government is unwarranted;

—If further investigation is warranted, permit contractor to conduct investigation and report back to government;

—Entire incident can be treated as a normal matter in the conduct of an ongoing business which does not warrant unusual problems or investigations or disclosures outside normal channels.

These criteria would not deter government prosecution of contractor violations, if warranted, and/or the level of appropriate government sanctions.

Conclusion

In today's climate of vigorous enforcement by the government, all government contractors need to institute a system of self-governance of some type. The government should establish clear and reasonable criteria for assessing contractor compliance when there are allegations of violation. ■

PROCUREMENT CAREERS INFO

MG Harry G. Karegeannes, Army Director for Contracting, Office of the Assistant Secretary of the Army for Research, Development and Acquisition, assumed control Oct. 1, 1987, of the career program responsibility for the Military Procurement Officer (FA 97) and Civilian (GS-1100 Series) Contracting and Acquisition career programs. Headquarters, Army Materiel Command, which relinquished proponent responsibility, will retain the Training With Industry (TWI) and Defense Contract Audit Agency (DCAA) Training Programs until further notice.

The FA 97 program has approximately 1,641 Army officers between the grades of 0-3 and 0-6. The GS-1100 series has approximately 9,757 civilians.

The procurement career program is an integrated set of functions promoting professional health of the procurement work force. Major responsibilities of the proponent include professional development, training requirements, educational programs, career counseling and guidance; also, coordination with the Total Army Personnel Agency (formerly CIVPERCEN and MILPERCEN) or career program qualifications and standards, and public relations, making policy recommendations to the ODCSPER on the structure and distribution of the FA 97 inventory.

An initial objective of the new proponency office is to form an FA 97 Army Proponency Policy Coordination Board comprising senior MACOM FA 97 personnel to meet periodically to provide field imput.

The Department of Army point of contact is Colonel A. Greenhouse, (703)756-2782 or AUTOVON 289-2782. ■

STATEMENT REQUIRED BY THE ACT OF AUGUST 12, 1970, SECTION 3685, TITLE 39, UNITED STATES CODE SHOWING THE OWNERSHIP, MANAGEMENT AND CIRCULATION OF

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2. Mail subscriptions paid and/or requested: 8,220

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E. Total distribution: 9,220

F. Copies not distributed: 153

1. Office use, left over, unaccounted, spoiled after printing: 397

2. Returns from news agents: None

G. Total distribution: 9,373

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2. Mail subscriptions: (paid and or other requested): 8,454

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D. Free distribution by mail crrier, or other means, samples, complimentary and other free copies: 1,000

E. Total distribution: 9,454

F. Copies not distributed

1. Office use, left over, unaccounted, spoiled after printing: 46

2. Returns from news agents: None

G. Total distribution: 9,500

Contract Awarded

Corning Glass Works has been awarded to a 2-year contract to supply high-strength fiber to the Naval Ocean Systems Center, Kailua, Hawaii, for the U.S. Navy SEARAY fiber-optic guided-missile program. Standard single-mode fiber and single-mode dispersion-shifted fiber will be provided by Corning's Advanced Fiber Products Department under terms of the contract, valued at close to $450,000. ■

STREAMLINING
THE PROCESS

Fred L. Adler

The Department of Defense acquisition process for major weapons systems, and for many other items, is lengthy, complex, and costly in time and dollars. It is alleged the process imposes unnecessary specifications, requires system performance that is not cost-effective, fails to involve developers early enough in the process to suggest reasonable alternatives, and does not always consider the use of suitable non-developmental items (NDI), which are off-the-shelf parts or those developed for other programs.

To reduce those problems and promote using innovative and cost-effective acquisition strategies, the Deputy Secretary of Defense issued Department of Defense Directive 5000.43, *Acquisition Streamlining*, in January 1986. That directive requires streamlining to be applied to the entire spectrum of acquisition activities and suggests early industry involvement in recommending cost-effective approaches. It defines acquisition streamlining as:

—Specifying contract requirements in terms of results desired rather than "how to design" or "how to manage"
—Precluding premature application of design solutions, specifications, and standards
—Tailoring contract requirements to unique circumstances of individual acquisition programs
—Limiting the contractual application to referenced documents to only those that are essential.

Streamlining is designed to produce acquisition strategies that can reduce cost and/or time of weapons systems acquisition and the systems' life-cycle costs and, at the same time, provide a system to meet the needs of the military user. To do so, it strengthens the partnership between the government and contractors by encouraging contractor innovation and eliminating or reducing impediments to effective action.

Acquisition personnel and program managers faced with the practical task of applying the streamlining process must answer such questions as: What streamlining techniques are available? When should those techniques be used? Which have the highest payoff? To help answer these and other questions, the Logistics Management Institute surveyed 30 major Army, Navy, and Air Force weapons systems programs that used streamlining approaches. Programs participating in the survey are listed in Figure 1.

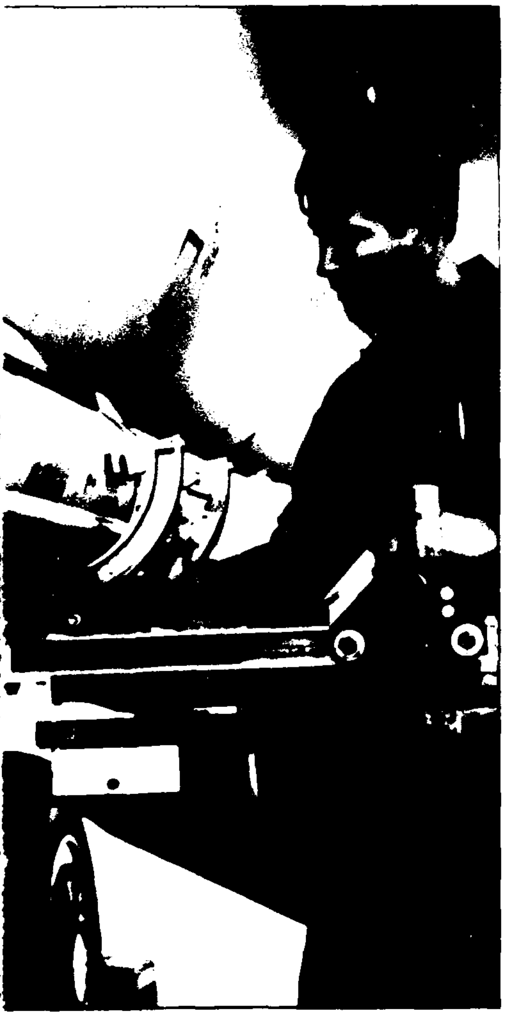
Before preparing the survey questionnaire, there were discussions with service streamlining advocates including senior personnel assigned to establish streamlining policies, procedures, and management controls and ensure their implementation. The questionnaire was designed to elicit information on the program structure and its acquisition status, a listing of streamlining plans and accomplishments, and a listing of streamlining innovations each program office believes to be important. Analysis of responses provides insights into the practical task of implementing the Department of Defense directive.

Initial result of the survey is a list of acquisition streamlining techniques most used. They are shown in Figure 2 with the number of the 30 programs in which they were used. Involving industry in the requirements generation process, using performance requirements in work descriptions, and tailoring specifications to specific acquisitions were the most frequently used streamlining procedures; using NDI was the next most popular. Although only the 15 most prevalent techniques are shown in the figure, some 40 different ones were reported.

Streamlining During Acquisition Phases

The analysis addressed when to use specific procedures. In new programs, acquisition streamlining can be applied early and continued thoughout all phases of acquisition: concept evaluation (CE), demonstration and valida-

The 12-foot-long, 335-pound AMRAAM will be used on the Air Force's F-15 and F-16 fighter, the Navy's F-14 and F/A-18, the German F-4F and the United Kingdom's Sea Harrier and Tornado ADV aircraft. The missile features a state-of-the-art radar that gives the pilot a "launch and maneuver" capability. AMRAAM provides the capability for multiple kills per engagement.



tion (DEM/VAL), full-scale development (FSD), and production and deployment. Of the 30 programs surveyed, half applied streamlining techniques during FSD, 8 during pre-FSD phases, and 7 during production/deployment.

In the pre-FSD phases, the key streamlining technique is using flexible performance requirements and specifications to allow consideration of design alternatives. For example, the Army LHX program office is asking contractors to evaluate the relationship between cost and performance and to suggest the most cost-effective performance requirements, within a range, for major subsystems. Such flexibility in design strongly encourages industry innovation; risk, cost, and time are reduced by emphasizing the use of proven technology. The Navy's PXM program is another example of pre-FSD streamlining. The program office encouraged challenges to system performance requirements, contract data requirements, and the timing and application of specifications. The program office required using NDI where possible to save time and cost.

In the full-scale development phase, the major element of acquisition streamlining is specification tailoring. Tailoring is the process of looking at each requirement to determine its pertinence and cost-effectiveness for a specific system acquisition and then modifying those requirements and the resulting military specifications to ensure that each contributes to an optimal balance between military user need and cost.

For its Tactical Missile System (ATACMS) program, the Army reviewed and challenged the required operational characteristics (ROCs) for non-essential features, and had potential contractors review and suggest changes to the specifications before final release. In the T-45TS program, the Navy tailored the specifications during the early acquisition phases. When strict cost limitations dictated the use of an existing airframe—the British Hawk trainer—specifications were again tailored during full-scale development to reflect the use of a flight-certified aircraft. Both programs reduced system acquisition cost through tailoring specifications, and both reduced time by using NDI.

Even in the production/development phase, opportunities still exist for streamlining. In that phase, using warranties and incentives, control of the number of change orders, and using NDI to reduce cost and time are major streamlining techniques. The Army's MSE was first streamlined in this phase. It was planned as a non-developmental, best-value, procurement program based on available equipment. No technical specifications were given in the request for proposal: bidders were free to propose hardware systems and concepts for supply and maintenance. Bidders proposed technical specifications based on existing systems and those specifications were modified as necessary during negotiation.

Effect of Streamlining Procedures

Of the 30 programs in the survey, most were streamlined by (1) eliminating or tailoring a number of product specifications and contract data requirements, (2) analyzing performance requirements to determine the extent to which they could be modified to reduce cost, (3) using NDI where possible and/or, (4) performing some full-scale development and production/development phase activities concurrently.

Responses show that substantial benefits can accrue from eliminating or tailoring product specifications; that is, eliminating unneeded specifications, the "how to" portions of valid specifications, and those specifications based on worst-case assumptions rather than on expected conditions.

In the Army AAWS-M program, for example, the original environmental requirements for operating altitude, exposure to rain, water immersion, icing, and nuclear survivability were stated in terms not likely to be encountered in operation. Those requirements were tailored by including only ones called for in the required operational characteristics, by drawing from experience with the TOW and DRAGON systems, and by soliciting advice from nuclear survivability experts. In the Navy Relocatable Over-the-Horizon Radar (ROTHR) program, tailoring the original ambient noise and air conditioning specifications is expected to save about $2 million per system.

The Air Force ATF and ATFE programs have used generalized development specifications that initially contain no numerical requirements—so-called MIL-PRIME documents. For example, ATF wheel brake capacity re-

■ *Mr. Adler is a Senior Research Fellow at the Logistics Management Institute. This article summarizes results contained in "Survey of Acquisition Streamlining in Weapon Systems Programs," which was prepared under a task order for the Assistant Secretary of Defense for Production and Logistics.*

Figure 1. Responding Streamlined Programs

MILITARY DEPARTMENT	PROGRAM
Army	Experimental Light Helicopter (LHX) Advanced Antitank Weapon System-Medium (AAWS-M) Family of Medium Tactical Vehicles (FMTV) Army Tactical Missile System (ATACMS) 120mm Mortar System Mobile Subscriber Equipment (MSE)
Navy	Undergraduate Jet Flight System (T-45TS) Joint Services Advanced Vertical Lift Aircraft (V-22) Replacement Inner Zone Air ASW Vehicle (CV IZ HELO) Amphibious Assault Ship (Multipurpose) (LHD) Patrol Combatant Multi-Mission Ship (PXM) Afloat Correlation System (ACS) Extremely High-Frequency Satellite Communications Terminals (EHF)
Air Force	Advanced Tactical Fighter (ATF) Advanced Tactical Fighter Engine (ATFE) Integrated Electronic Warfare System (INEWS) Worldwide Information System (WIS) Modernization Advanced Medium Range Air-to-Air Missile (AMRAAM) Peacekeeper Intercontinental Ballistic Missile (ICBM) Small ICBM (SICBM) MILSTAR Local On-Line Networking System (LONS) Joint Surveillance Target Attack Radar System (JSTARS) Anti-Radiation Missile (ARM) Decoy Titan T34D7 Space Booster/Complementary Expendable Launch Vehicle (CELV) Direct Airfield Attack Combined Munition (DAACM)

Photo Courtesy of Boeing

The maiden mission of Boeing's Inertial Upper Stage begins with the fiery liftoff atop a U.S. Air Force Titan-34D from Cape Canaveral, Fla. Boeing builds the IUS for the Air Force for use as upper stage for the Space Shuttle as well as the Titan-34D.

quirements (stopping performance characteristics, number of operational landings, means for determining brake wear, and structural failure conditions) are described in a single specification with one appendix referring to two other specifications; previously, for the landing gear specifications alone, 13 specifications with 256 related references were used. These MIL-PRIME documents, which were developed by the Air Force Aeronautical Systems Division, are being used to provide requirements that specify what is needed (in numerical terms) and to eliminate those that tell the contractor how to build it.

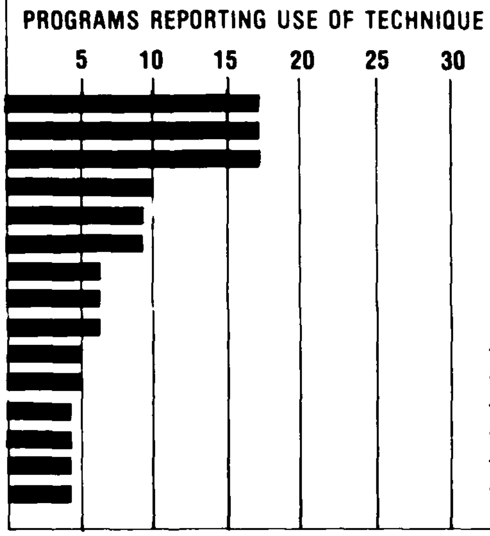
Tailoring contract data requirements, like product specifications, has a high payoff. Elimination of unneeded requirements, tailoring others, and using contractor formats are three effective streamlining techniques. The challenge here is to identify essential data and know when contractor formats are satisfactory. In the Army MSE program, 300 data items originally required were reduced to 27; the Air Force Anti-Radiation Missile (ARM) Decoy program tailored more than 70 percent of the contract data items.

The acquisition streamlining initiative places emphasis on the long-established Department of Defense policy that requirements be examined carefully in light of all relevant factors. Streamlining encourages analytical tradeoffs among performance characteristics and costs. In that regard, the Army LHX acquisition gave preliminary system specifications in banded ranges to encourage each offerer to make tradeoffs among performance characteristics for design optimization. The only fixed requirements dealt with the delivery schedules, reliability, and goals for competition. The Air Force ATF program involved tradeoffs by contractors from the beginning of the program. They critically examined the sensitivities of the performance requirements to each design specification.

The Air Force ATF program involved tradeoffs by contractors from the beginning of the program.

A streamlining technique that enhances the government's flexibility is soliciting prices for various desirable performance characteristics, weighing the cost and performance alternatives,

Figure 2. Streamlining Techniques Reported in the Survey



STREAMLINING TECHNIQUE

1 Involve contractors early
2 Write work statements in terms of required performance
3 Tailor specifications to specific acquisition
4 Use NDI
5 Require guarantees/warranties
6 Use preplanned product improvement (P³I)
7 Eliminate one or more acquisition phases
8 Structure to reduce risk (prototype, etc.) to expedite full-scale development
9 Ensure requirer/user interaction
10 Use contractor management systems/data formats
11 Use incentives to induce streamlining
12 Afford contractor maximum performance flexibility
13 Adapt contractor, industry, foreign specifications
14 Reduce test requirements by using available data on similar items
15 Ask contractor to recommend streamlining means for future phases

and selecting among the alternatives submitted. This technique is exemplified in the Army MSE program in which contractors proposed systems with different mixes of performance characteristics, such as area coverage, degree of fixed and mobile subscriber access, and terminal capabilities. Bidders were asked to include five firm, fixed-price (FFP) production options, FFP spares for the life of the program, and performance warranties.

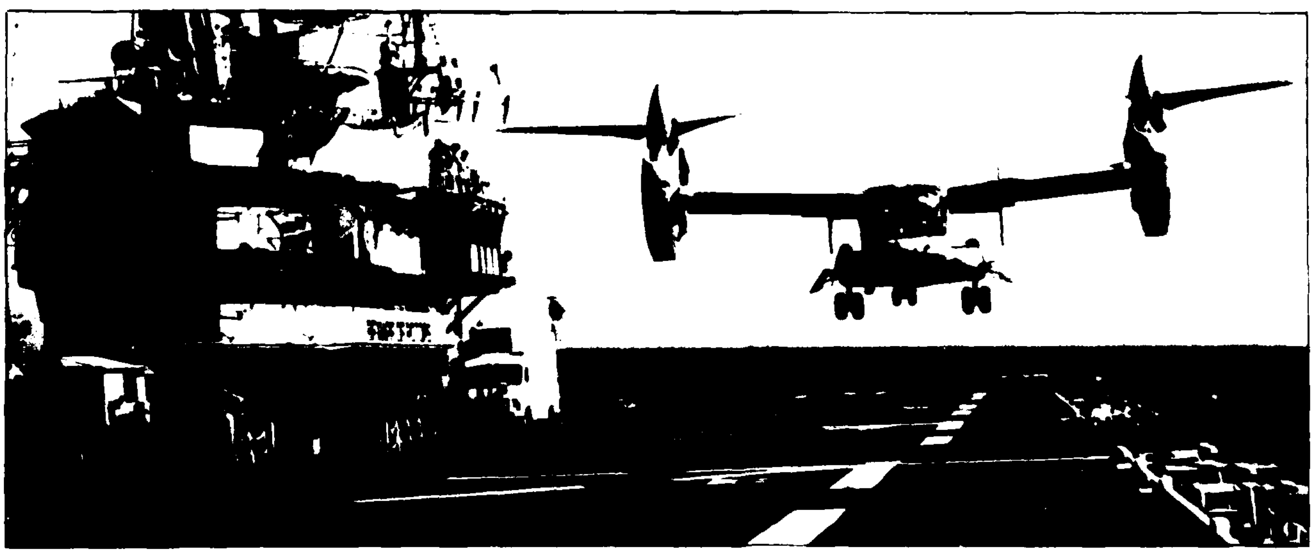
A primary goal of streamlining is to shorten the acquisition cycle time from initiation to deployment. In the survey, two specific techniques for shortening that time were reported: emphasis on the use of NDI and the use of concurrency between the full-scale development and production/deployment phases.

The Army had dramatic success with emphasis on NDI. In the 120mm Mortar program, the weapon and its ammunition were non-developmental, and probably more than 2 years were saved in development time. The Navy also has taken the NDI approach.

Streamlining should shorten acquisition cycle time from initiation to deployment.

Foreign components are being used in the Ship Launched Electronic Decoy (SLED) (Australian launchers) and T-45TS (British aircraft) programs; Air Force operational system design and components are used in the ROTHR program; off-the-shelf avionics in the V-22 program; and approved-for-production items in the PXM program. The Air Force is similarly pursuing the CELV program as an evolutionary design, and it uses many mature components in the DAACM program.

While the overlapping of acquisition phases (concurrency) shortens the acquisition cycle time, it should only be considered in cases where the associated technical risk has been thoroughly analyzed and found acceptable. Since the Air Force CELV program, for example, is based largely on a system



One of the most important changes in the amphibious tactics of the Marine Corps on the expanded battlefield of the 1990s will stem from improvements provided by new ship-to-shore systems, such as the tilt-rotor MV-22A Osprey, shown.

Figure 3. Major Reported Program Benefits

PROGRAM	MAJOR REPORTED SAVINGS: DEVELOPMENT TIME SAVED	MAJOR REPORTED SAVINGS: COST AVOIDANCE ($MILLIONS)	PRINCIPAL REASONS FOR SAVINGS
MSE	5-10 years	--	Use of NDI and industry
120mm Mortar	2 years	--	Use of NDI
AAWS-M	1-2 years	--	Combine CE and DEM/VAL in "proof-of-principle" phase
CV IZ HELO	3-5 years	1,510	Use of broad performance specifications, industry involvement, and NDI
V-22		355	Tailoring specifications and contract data requirements and limiting specification tiering
ROTHR	2 years	2.06/system	Modifying non-cost-effective performance requirements based on design tradeoffs prior to FSD
DAACM	2 years	--	Use of short-term risk-reduction contracts prior to FSD

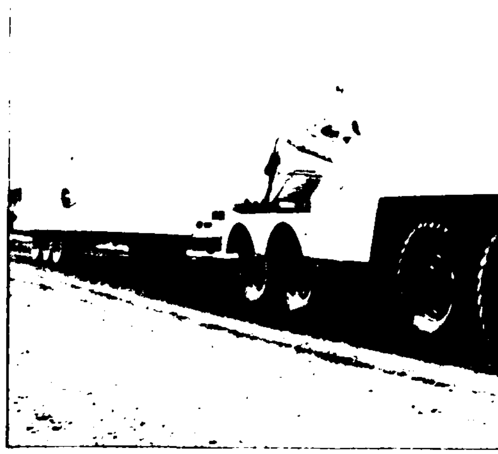
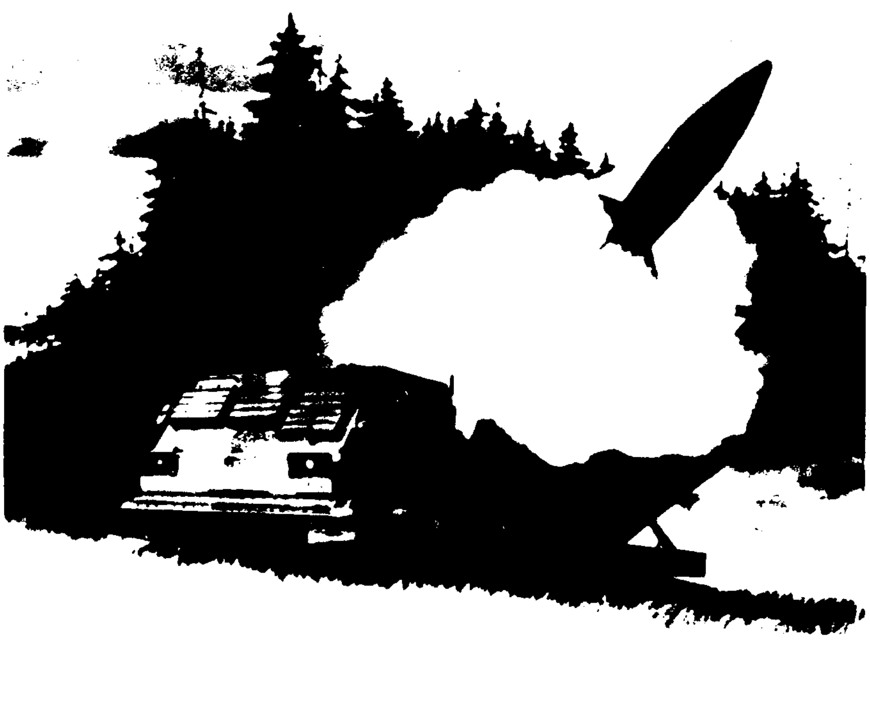


Photo courtesy of Boeing

The Small ICBM Hard Mobile Launcher is part of the next generation of ballistic missile systems expected to be deployed in the 1990s. It is designed to transport and launch a Small ICBM from selected U.S. military installations.

A long-range guided missile, Army TACMS is packaged in MLRS-size launch pod containers and launched by MLRS crews from dual-capable MLRS launchers. The initial antipersonnel, antimateriel (AP/AM) warhead, filled with lethal quantities of M74 munitions, will defeat company-size soft targets deep within the enemy's rear echelons. A planned smart munitions warhead, equipped with terminally guided submissiles, will defeat ballistic missile sites or delay and disrupt an entire maneuver battalion.

Photo courtesy of LTV

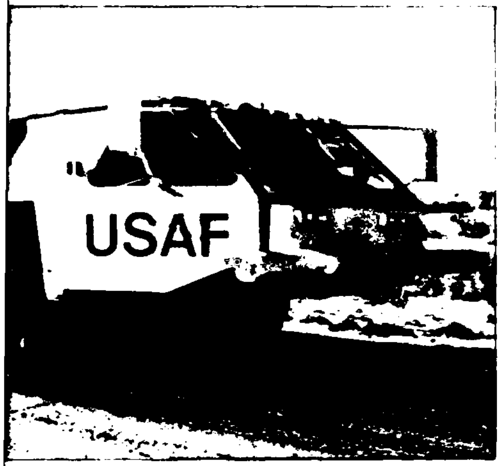


that has long been in the Air Force inventory, development and limited production can proceed jointly. In programs in which large numbers of systems are being acquired, such as the Air Force AMRAAM program, initial production tooling can often be started during full-scale development.

Reducing the number of contract awards and shortening the source-selection process can save acquisition time. The survey indicated that the Army 120mm Mortar program and the Navy T-45TS program requested proposals from industry for concurrent development and production options, thereby necessitating only a single competitive award for each program. The Air Force Ballistic Missile Organization has developed a streamlined source-selection approach that has reduced the average time from release of requests for proposals to contract award to 101 days. The approach calls for fewer evaluation factors, proposals limited to 100 pages, 10-person maximum evaluation boards, contractor oral presentations, and no more than 9 weeks for evaluation of proposals.

Selected Survey Results

In the survey response, several programs reported major benefits or anticipate such benefits either in the form



of shortened acquisition time or of avoided additional development costs. Figure 3 summarizes those savings and indicates how they were achieved. For example, the Army MSE program expects to save from 5-10 years in development time by using NDI. The Navy anticipates almost $1.9 billion in cost avoidance on the CV IZ HELO and the V-22 programs by using broad performance specifications, involving industry early, emphasizing the use of NDI, tailoring specifications and contract data requirements, and limiting the use of referenced specifications. The Navy ROTHR program indicated life-cycle cost avoidance of more than $2 million per system by modifying requirements, using industry tradeoff studies. The number of independent radar antenna elements was reduced, receiver design was simplified, power amplifier performance was lowered, and the ionospheric sounder was procured as an off-the-shelf item with significant savings in acquisition costs and time.

Effect of Streamlining on Competition

Streamlining must not succeed at the expense of competition. Shown in Figure 4 are techniques used by streamlined programs in the survey, either for competition in all phases through the production/deployment phase or for competition in the phases before the production/deployment phase. The experience shown in that table indicates that competition and streamlining are compatible.

Streamlining's Future

Where then does streamlining go from here? Several challenges remain: in institutionalizing streamlining by in-

Figure 4. Competition in Streamlined Programs

PROGRAM	COMPETITION EXTENT	COMPETITION IN PRODUCTION
120mm Mortar	Full (NDI emphasis)	Yes
AAWS-M	Low-rate production by team; high-rate production by competition among team members	Yes
LHX	Four preliminary design contractors; each furnishes a plan for dual-source production competition	Yes
INEWS	Five CE-phase teams; two DEM/VAL phase teams; one FSD-phase team; two production contracts	Yes
AMRAAM	Leader-follower procedure used	Yes
ATF	Seven CE-phase contractors; two DEM/VAL-phase teams; competition in FSD and production/deployment phases	Yes
MILSTAR	Two leader-follower teams in FSD phase; two production contacts	Yes
WIS	Full (NDI emphasis)	Yes
V-22	Full (for all subsystems)	Yes
FMTV	Three prototypes to be tested; one production contract	No
EHF	Three DEM/VAL contractors; two FSD contractors; one production/deployment contractor	No

Lockheed Corporation, the Boeing Company and General Dynamics Corporation announced on July 1 a teaming agreement for development of the Advanced Tactical Fighter (ATF) for the U.S. Air Force. The agreement includes design, manufacture, test and support of the ATF.

corporating streamlining in the acquisition regulations (especially guidance relative to the acquisition process); in continuing to develop and deploy those tools identified as best meeting streamlining objectives; and in training the entire acquisition community (program managers, contracting officers, engineers, lawyers, etc.) in their use.

Further cultural change is needed since many within the community still view specifications and data as the only practical way to protect Department of Defense interests. This change can be accomplished in part by changing the Federal Acquisition Regulation (FAR) and the Department of Defense FAR Supplement to indicate clearly a preference for streamlined acquisition contracting and to provide the necessary standard provisions and clauses for its use. Change can be accomplished by further institutionalizing acquisition streamlining in each Department of Defense component, following what the Army has done in defining its own Army Streamlined Acquisition Process.

A number of key tools must be spread throughout the acquisition community. Emphasis on the proper development and use of system performance requirements based on balancing cost and performance is fundamental. This must be followed by means to formulate better specifications. Automated tools and data bases to access and tailor specifications are needed. Specification tiering—calling out successive levels of detailed specifications—must be curtailed. Better specification formats that encourage tailoring must be made available. In coordination with industry, the Department of Defense is identifying obsolete, outdated, and burdensome specifications for updating or deletion.

In addition to improving requirements and specifications, streamlining must be extended to other aspects of acquisition decison-making. A streamlined acquisition organization must be implemented, one that eliminates unnecessary reviews and places decision authority at the lowest possible level. Source selection procedures should be simplified and streamlined, and oriented to enable the government to obtain best value.

To continue the streamlining momentum, oversight of streamlining progress must be continued. Additional feedback mechanisms are needed to enable the Department of Defense management to assess streamlining accomplishments. Oversight of streamlining is being improved, including development of additional case studies documenting successful practices as they are identified.

Training in acquisition streamlining needs to be emphasized and become readily available. Better incentives for the Department of Defense and industry personnel are needed to encourage streamlining. To this end, an integrated Department of Defense-wide training program is under development. Incentives for the Department of Defense and industry are being created and implemented. A leadership conference for acquisition streamlining advocates in the field is planned.

These actions should go a long way toward meeting the challenges of making acquisition streamlining a way of life throughout the acquisition community, and an integral part of all key acquisition program management functions. ■

The Army conducted an Executive Workshop from 19 to 23 October 1987. The DSMC provided the coordination and facilitation of this first course on "How We Do Business." General Maxwell R. Thurman, Commander of the Training and Doctrine Command, and General Lewis C. Wagner, Jr., Commander of the Army Materiel Command, were the co-hosts of this course with John Snoderly and Kris Kristensen of DSMC providing the classroom facilitation. Some 48 distinguished guest speakers participated with the 35 General Army Officers and senior civilians. A frank and open discussion of the acquisition issues facing the Army was held and action items assigned to fix many of the problems.

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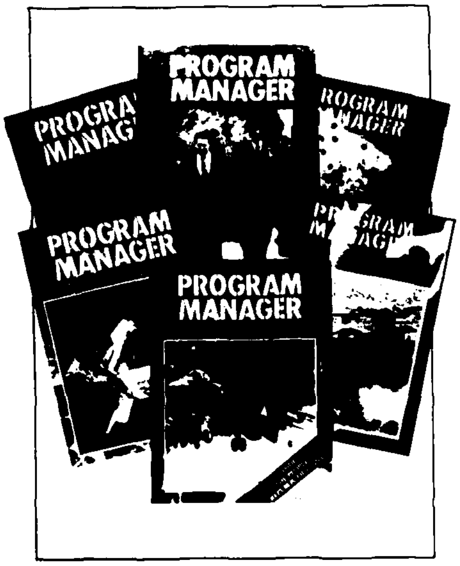

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